DOCUMENT RESUME

ED 133 426	CE 007 582
TITLE	Diesel Engine Services. An Instructor's Guide for a Program in Trade and Technical Education. Automotive Industries Occupations.
INSTITUTION	New York State Education Dept., Albany. Bureau of Continuing Education Curriculum Development.; New York State Education Dept., Albany. Bureau of Secondary Curriculum Development.
REPORT NO	VT-103-436
PUB DATE	[76]
NOTE	156p.
EDRS PRICE	MF-$0.83 HC-$8.69 Plus Postage.
DESCRIPTORS	*Auto Mechanics; *Curriculum; Curriculum Guides; *Diesel Engines; Engines; *Equipment Maintenance; Industrial Arts; Job Skills; *Mechanical Skills; *Mechanics (Process); Post Secondary Education; Secondary Education; Teaching Guides; Technical Education; Trade and Industrial Education; Units of Study (Subject Fields)

ABSTRACT

Designed to prepare students to be engine mechanics working on automotive and large stationary diesel engines, this instructor's guide contains eight units arranged from simple to complex to facilitate student learning. Each contains behavioral objectives, a content outline, understandings and teaching approaches necessary to develop the content, including page references for selected textbooks, and review discussion questions and statements. Unit 1 presents an introduction to the parts and functions of the diesel engine, the use of basic hand tools, job safety, and the relationship between this course and perceived occupational goals. Cylinder heads and their function, analysis, removal, cleaning procedure and valve adjustment are the focus of unit 2. Engine removal, disassembly, and cleaning are discussed in unit 3. Engine parts inspection, unit 4, includes inspecting engines for cleanliness, cracks, and serviceability; determining reasons for part failure or wear; listing all parts requiring service; and listing and ordering replacement items. Unit 5 involves the student in engine part repair, reassembly and reinstallation. Engine accessories such as air conditioners, starting systems, fuel filters and others are examined in unit 6. Unit 7 concerns engine diagnosis and tuneup, and unit 8 focuses on injection systems and controls. Also included are a sample final examination, notes on using audiovisual materials and on preparing and using transparencies, a glossary, a directory of diesel engine and equipment manufacturers from which instructional materials are available, and a bibliography including lists of textbooks, reference books, pamphlets and charts, films, filmstrips and slides, film loops, transparencies and transparency masters. An appendix includes safety information, material on metric measurement, conversion charts, and worksheets. (TM)

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Automotive Industries Occupations

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AN INSTRUCTOR'S GUIDE FOR A PROGRAM IN

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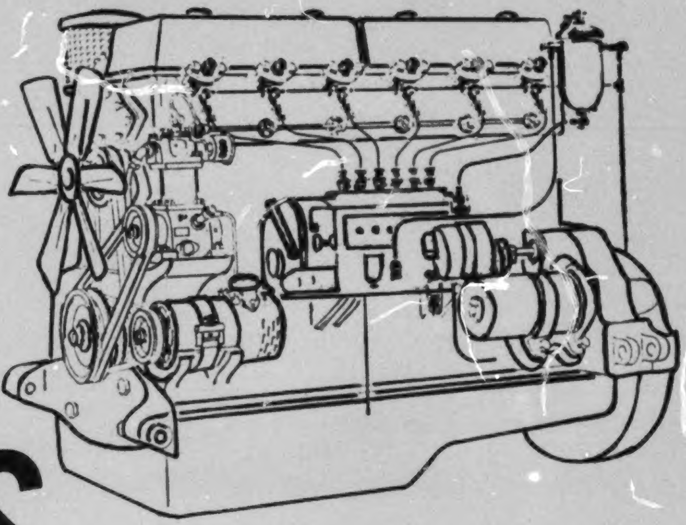
DIESEL ENGINE SERVICES



TRADE AND TECHNICAL EDUCATION

VT-103-436

CE007582

THE UNIVERSITY OF THE STATE OF NEW YORK / THE STATE EDUCATION DEPARTMENT
BUREAU OF CONTINUING EDUCATION CURRICULUM DEVELOPMENT
BUREAU OF SECONDARY CURRICULUM DEVELOPMENT / ALBANY, NEW YORK 12234

FOREWORD

There is an increasing need for people who are skilled in maintaining and repairing diesel engines. This publication is designed to assist instructors in organizing training programs for individuals seeking employment in the field of diesel engine service. The instructional content may be used in secondary schools and adult occupational education programs.

Appreciation is expressed to Gerhard Klinitzke, diesel mechanic instructor at Nassau County BOCES, Westbury, for his efforts in developing the instructional materials. Assistance relating to content was provided by Charles A. Stebbins, associate in the Bureau of Trade and Technical Education. The project was coordinated and the manuscript prepared for publication by Nelson S. Maurer, associate in the Bureau of Continuing Education Curriculum Development.

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MESSAGE TO THE INSTRUCTOR

Diesel Engine Services is designed to prepare students to be engine mechanics working on automotive and large stationary diesel engines. The units are planned to be presented in numerical order to facilitate learning by going from the simple to the complex. In order to provide an adequate learning situation, there should be a sufficient number of diesel engines so that no more than two students have to work on an engine at any one time. The unit on injection systems should be presented only if the proper specialized equipment is available for student use.

This guide suggests methods and materials that should enrich a course and help achieve a more effective presentation. The general objectives for each unit are stated in terms of performance activities that the student is able to do as a result of the instruction. The standards, as determined by the instructor, should be at least the minimum proficiency necessary for entry employment in the area of diesel engine services. More detailed objectives may be developed and these also should be stated as observable behavior that the learner is able to do when applying the skills and knowledges acquired. The left-hand column of each unit contains a suggested topical outline; the right-hand column gives related factual information, as well as suggested teaching techniques and page references for selected textbooks. At the conclusion of each unit, topics for review discussion are included. Also, a sample final examination is provided.

The use of instructional aids will enhance and clarify the presentation of material. A list of suggested aids is given in the bibliography. Excellent instructional materials are available from various diesel engine and equipment manufacturers which are listed in the Directory. Useful teaching aids may be fabricated from discarded equipment and by producing your own slide sets and instruction sheets.

New instructional aids are usually listed in such professional education magazines as *School Shop* and *Industrial Education*. Technical information relating to diesel engines may be found in such trade publications as *Diesel Equipment Superintendent* and *Diesel and Gas Turbine Progress* and in manufacturers' service bulletins.

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UNIT 1

INTRODUCTION

OBJECTIVES

The student will be able:

- To assess the value of the course in meeting his perceived occupational goals
- To demonstrate appropriate work habits and attitudes during training and on the job
- To demonstrate a high regard for the safety of himself and his fellow workers during training and on the job
- To use basic hand tools and machines skillfully and accurately
- To explain the basic operation of a four-stroke and a two-stroke cycle diesel engine
- To identify and explain the function of the main parts of a diesel engine
- To identify and use fastening devices appropriate for the need.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
I. Introduction	Discuss the increasing importance of the diesel engine. Indicate that there is a growing need for qualified diesel mechanics and explain the job opportunities available to trained and qualified mechanics. The purposes of the course are: • To provide training in the field of diesel service for individuals in occupational and vocational programs • To permit individuals working as automotive mechanics, mechanics' helpers, apprentices, and owners of diesel engines to acquire the skills necessary to service and repair diesel engines.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
II. Overview of Course	Indicate that the course content will cover servicing and repairing of diesel engines including: • Removal and disassembly of head and block • Cleaning and inspection of engine parts • Repair and reassembly of parts • Maintaining engine accessories • Tuneup of engine • Rebuilding and testing injectors Point out that in addition to the theory work presented in class, students will have the opportunity of gaining practical experience by working on live jobs. Indicate the length of each session, number of sessions, procedures to be followed in class, reasons for homework, and the expectations for each class member. Also, point out the importance of regular class attendance. Emphasize that there will be quizzes and tests throughout the course and a final examination at the end of the course.
A. Individual needs	*Determine the background and needs of each student. Use this information to adapt the course content to meet as many of the individual needs as possible, keeping in mind the available equipment.* *Develop a card data file for each student, listing address, telephone number, needs, goals, training, work experience, and other pertinent information. This file will be valuable in giving individual aid during the course. Also, it will help to maintain contact with students after employment. Many times former students can provide up-to-date trade information, training aids, and placement assistance.*

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
B. Work habits and attitudes	Discuss the importance of good work habits and show how these might aid an individual in maintaining and improving his position. Include such items as: • Sense of responsibility to employer and other employees • Appreciation of safety rules and regulations • Accuracy and speed Discuss the attitudes that employers expect to find in employees. Indicate that many times the cause for a worker's dismissal is related to his poor work habits and not to his lack of knowledge. Emphasize the importance of developing good work habits and desirable attitudes during the course. (Ref. What Employers Want; Why Young People Fail To Get and Hold Jobs)
C. Engine assignment	Explain that at least two students are assigned to each shop engine and they are responsible for all parts removed and for having the engine in operating condition at the end of the course. Point out that students may form their own work teams if they desire.
D. Shop cleanup	Explain the procedure and assignments for cleaning up the shop at the end of each period.
III. Course Requirements	
A. Prerequisites	*To be able to profit from the instruction, students should have a basic knowledge in the following areas:* • *Mathematics* • *Science* • *Automotive engines* • *Metal work* • *Shop safety*

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	Give quizzes to determine the student's knowledge in the following: • *Basic mathematics* • *Basic science* • *Measurement* • *Shop safety*
B. Textbook	*If a textbook is to be used, give its title, price, and source. Arrange for a group order.* Point out that textbooks given out on a loan basis must be returned in good condition or be paid for. Have students sign for textbooks issued.*
C. Notebook	Indicate that students must keep all the printed material distributed in class along with notes taken during demonstrations and class discussions in a loose-leaf notebook. Explain how to organize the notebook to make it useful. *Check each student's notebook occasionally to see if it is of the proper quality.*
IV. General Safety	Review general rules of safety for the service garage employee. (Ref. A, pp. 47-49; General Safety Instructions; Safety in Your Future; Your Guide to Safety as a Service Garage Employee) *Use films or transparencies that deal with safety to emphasize the importance of practicing safe work procedures when performing any type of repair work.* Ask students to discuss their own experiences with accidents and have them indicate the safety procedures that should have been followed. Discuss the dangers of horseplay and hot rodding and give examples of the possible consequences of each.

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*Reference citations are shown on page 109.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	Show the location of fire extinguishers and discuss fire control procedures.
	Explain specific safety procedures for using the following: • Hydraulic pullers and presses • Lifts and jacks for vehicles • Compressed air (See Appendix 1) • Spring compressors • Drill presses and grinders • Portable electric tools
	Require each student to take and successfully pass a general shop safety test before being allowed to operate any of the machines.
A. Protective clothing	Point out the advisability of wearing coveralls during the work sessions. Indicate some local sources and approximate prices.
B. Safety glasses	Indicate the regulations relative to eye safety. See Appendix 2.
	Arrange for a group purchase of approved safety glasses for those who wish to have their own glasses.
V. Diesel Engine Operation	Explain and illustrate the basic operation of the following: • Four-stroke cycle diesel engine including action in the cylinder during two revolutions of the crankshaft. • Two-stroke cycle diesel engine, including action in the cylinder during one revolution of the crankshaft.
	(Ref. A, pp. 37-54; Ref. B, pp. 60-66; Ref. C, pp. 1-1—1-19; Ref. D, pp. 1-27; Ref. F, pp. 1-8)
	Use cutaway models, handout sheets, and transparencies to assist in presenting the topic.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	Explain how the three requirements necessary to make any internal combustion engine operate are satisfied in the diesel engine. Include the following points: • Ignition – by temperature of compressed air • Air fuel mixture – by injecting metered, atomized fuel into cylinder at end of compression stroke • Compression – by compressing the volume of air in the cylinder with the piston (Ref. A, pp. 46, 47; Ref. C, pp. 1-1—1-19)
	Explain the basic function, design, and operation of the following: • Cylinder head • Cylinders • Ports • Pistons, rings, and pins • Connecting rods • Crankshaft • Flywheel • Timing gears • Camshaft • Valves (valve overlap) (Ref. A, pp. 37-82; Ref. B, pp. 100-137; Ref. C, pp. 2-2—2-63; Ref. D, pp. 40-58)
	Be sure students are taking notes during the class discussions.
	Check student's knowledge of the diesel cycle and function of the various parts by frequently asking questions.
VI. Basic Mechanics	*If the students do not have the necessary mechanical skills, present the following items early in the course.*
A. Basic Tools and Machines	Explain and demonstrate the uses, types, and safe handling of the following basic tools

CONTENT OUTLINE — UNDERSTANDINGS AND TEACHING APPROACHES

and machines:

- Hammers
- Screwdrivers
- Chisels
- Hacksaws
- Files
- Pliers
- Punches
- Scrapers
- Drills
- Wrenches
- Tap and dies
- Thread restorers
- Screw extractors
- Reamers
- Pullers
- Presses
- Electric hand drills
- Drill presses
- Bench grinders
- Portable grinders
- Cleaning equipment
- Lifting equipment

(Ref. B, pp. 22-50; Ref. H, pp. 1-1—3-20, 7-1—7-11; *Shop Tools* by John Deere)

Basic tool skills may be improved by having students make valve, tappet, and similar parts racks that are required during engine disassembly. Have students work on something useful and avoid busy work. Provide additional practice during actual engine work.

Record students proficiency with tool usage on a progress report form.

B. Measuring tools

Explain and demonstrate how to use the following measuring tools:

- Rules
- Squares
- Dividers
- Micrometers
- Calipers
- Vernier gauges
- Feeler gauges
- Dial gauges
- Telescoping gauges
- Spring testers
- Small bore gauges
- Protractors

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

(Ref. B, pp. 40-44; Ref. H, pp. 2-1—2-13; *Shop Tools* by John Deere)

Have students practice using and reading precision measuring tools. See Appendix 3.

Record students proficiency with measuring tools on a progress report form.

Explain the metric system of measuring. Point out how to convert inches to millimeters and vise versa and the reason for making the conversion. See Appendices 4 through 8.

C. Fasteners and Fittings

Explain and demonstrate the types, selection, and uses of the following fasteners and fittings:

- Machine screws
- Set screws
- Cap screws
- Nuts
- Washers
- Lock washers
- Lock rings
- Lock plates
- Cotterpins
- Safety wire
- Keys
- Key ways
- Rivets
- Tubings
- Pipe fittings
- Flare fittings
- "O" fittings
- Sheet metal screws
- Splines
- Plugs
- Compression fittings
- Hoses
- Hose connectors
- Hose clamps

(Ref. B, pp. 22-29; Ref. H, pp. 3-1—3-20, 5-1—5-19)

Have students select and identify various types of fasteners and fittings and explain when they should be used.

Have students demonstrate proficiency in cutting

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

tubing and making single and double flare fittings.

Further practice should be done during the actual engine work.

D. Soldering, Brazing, and Welding

Provide students opportunities to become proficient in the following:

- Soldering
- Brazing
- Gas Welding
- Arc Welding

(Ref. H, pp. 8-1—8-20)

Students may acquire these skills by attending basic instructions in a welding shop along with a few practice sessions.

Review Discussion

1. Why is safety emphasized when working on diesel engines?
2. Describe how to use five precision measuring tools needed by a diesel mechanic.
3. Describe the function of the main parts of a diesel engine.
4. Describe the operation of a four-stroke cycle diesel engine.
5. Explain how the two-stroke cycle diesel differs from the four-stroke cycle diesel.
6. Explain the advantages of using the metric system for measuring.
7. Explain how the three requirements necessary to make an internal combustion engine operate are satisfied in a diesel engine.
8. Explain the importance of an employee developing and maintaining good work habits.
9. Explain why diesel engines are referred to as a compression-ignition engines.
10. Explain why diesel engines are constructed heavier than gasoline engines of the same size.

UNIT 2

CYLINDER HEADS

OBJECTIVES

The student will be able:

- To take a compression test and analyze results
- To list the reasons for removing a cylinder head
- To remove, disassemble, clean, and inspect cylinder heads and component parts
- To grind valves, valve seats, and rocker arm contacts
- To replace valve guides, crosshead guides, valve seats, injector tubes, combustion chambers, and rocker arms studs
- To reinstall cylinder head and adjust valves

CONTENT OUTLINE — UNDERSTANDINGS AND TEACHING APPROACHES

I. Compression Test

Explain why it is important to make a compression test. Demonstrate how to make a compression test including:

- Removing injector
- Installing compression gauge
- Turning engine at specified r.p.m. to get correct reading (fuel rack in no fuel position)

Explain what a low compression test indicates. Repeat the compression test using oil and explain how this procedure is used to check the condition of the piston rings. (Ref. C, pp. 12-11—12-12; Ref. F, pp. 22-23; Ref I, p.23)*

Have students practice taking compression tests on various engines and analyzing readings correctly.

Caution students of the dangers related to open, high pressure fuel lines and injection discharges.

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*Reference citations are shown on page 109.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
II. Removal	Explain and demonstrate how to remove a cylinder head including: • Draining cooling system • Removing and marking the position of fuel lines and water connections and capping them with plugs • Removing other attached accessories • Removing manifolds • Removing, wrapping, and storing injectors to prevent damage to discharge nozzle • Removing valve cover, rocker arms, pushrods, valve bridge, and roto caps. • Loosening cylinder head bolts or nuts in proper sequence • Removing large heads with a floor crane or hoist • Making an immediate inspection of head surface for cracks and/or water marks before disturbing carbon deposits (Ref. B, pp. 265-271; Rec. C, pp. 2-1—2-4; Ref. H, pp. 13-1—13-2) Explain why it is important to follow the procedures and specifications given in the manufacturers shop manuals.
III. Disassembly	Explain and show how to disassemble a cylinder head. During the demonstration, discuss the following: • Selection of special tools • Use of a valve rack for storing and keeping parts in order • Use of safety glasses • Removal of burrs or carbon from valve stem

- Notation of any excessive carbon deposits or damage to valves or seats (for use during the inspection procedure)

(Ref. B, pp. 271-273; Ref. C, pp. 2-1—2-4; Ref. H, pp. 13-2—13-3)

Have students practice removing and disassembling cylinder heads on assigned engines. If valve racks are not available, have students make them out of angle iron and welding wire. This will give students practice with the hack saw and drill press.

IV. Cleaning

Explain and demonstrate how to clean a cylinder head and component parts. Discuss the following during the demonstration:

- Removing deposits with rigid and flexible scrapers
- Cleaning valves with rotating wire brushes (Ref. C, pp. 2-11—2-13)
- Cleaning parts using a steam cleaner, acid bath, hot tank, high pressure washer, low volatility tank, and glass peening machine
- Protecting eyes and skin when using high pressure or chemical cleaning solutions (See Appendix 2.)
- Prevent damage to parts during scraping and cleaning operations

(Ref. B, pp. 259-279; Ref. C, pp. 2-4—2-16; Ref. H, pp. 9-1—9-9; Ref. I, pp. 245-247)

Have students clean cylinder heads and component parts on assigned engines. Check students for proper work procedures. Be sure that all safety precautions are being followed.

V. Inspection

A. Tools

Review the use of the following inspection tools:

- Micrometers

- Dial indicators
- Telescoping gauges
- Small bore gauges
- Straight edge and feeler gauges

(Ref. B, pp. 259-278; Ref. C, pp. 2-4—2-5, 2-10—2-14; Ref, H. pp. 2-1—2-14)

Demonstrate how to use the following inspection tools and equipment:

- Magnifiers
- Magnetic crack finders
- Pressure testing equipment

B. Procedure

Demonstrate how to inspect a cylinder head and record pertinent data on a worksheet. (See Appendix 9.) Include such items as:

- Sealing surface—warpage or damage
- Head—cracks using magnetic crack finder or pressure (Explain how cracked cylinder heads are repaired commercially.)
- Valve guides and bridge stems and guides—wear
- Valve seat
- Valves—stem wear, burned face, and warpage
- Injector sleeves (tubes)
- Valve spring—height, squareness, and tension
- Cooling ducts and nozzles, if used (Ref. B, p. 127)
- Valve rotators, keys, and spring retainers
- Combustion chambers, if installed in head
- Rocker arm shafts or studs—bushing wear, unrestricted oil holes, and valve contact area wear

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Lubrication passages
	(Ref. B, pp. 277-296; Ref. C, pp. 2-4—2-16; Ref. H, pp. 13-3—13-13; Ref. I, pp. 258-264)
	Have students practice inspecting cylinder heads and component parts on assigned engines and have them record their findings on an engine head worksheet. (See Appendix 9.) Be sure students follow manufacturers' specifications and procedures.
VI. Repair	Explain why valve seats, guides, and waterspray nozzles have to be changed first whenever the head needs to be machined. Explain and show how to service the following parts including:
A. Valve guides and/or valve bridge guides	• Changing or reaming valve guides (observing proper position, depth, and clearance) (Ref. C, pp. 2-14—2-15; Ref. H, pp. 13-9—13-13)
B. Valve seats	• Removing valve seats (insert and screw-in type) (Ref. H, p. 13-13) • Measuring and reconditioning valve seat counterbores (Ref. H, pp. 13-14—13-16) • Selecting and installing valve seats (material, dimension, and methods of installation) • Replacing swirl defectors if used • Grinding valve seats (proper angle, seat width, concentricity, and dimension)
	(Ref. B, pp. 273-286; Ref. C, pp. 2-12—2-14; Ref. F, p. 174; Ref. H, pp. 13-16—13-20)
C. Water holes or nozzle	• Removing nozzle • Reconditioning bore • Selecting nozzle or waterhole repair sleeve
D. Injector tube	• Removing tube

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Cleaning tube seat • Reinstalling new tube • Reaming injector seat *On most heads, a pressure test should be made after the injector tube has been replaced. Consult manufacturer's manual for specific procedures.*
E. Cylinder head	• Machining gasket surface • Measuring and selecting gasket • Cutting new seal grooves, if used • Changing rocker arm studs • Changing fusable and core plugs • Changing combustion chambers
F. Valves	• Gringing valve face and stem end (Show how to handle and dispose of sodium-cooled valves.) (Ref. B, p. 128) • Rechecking valve margin, valve head depth, and stem height • Capping, if required (Ref. B, pp. 272-273; Ref. C, pp. 2-10—2-11; Ref. H, pp. 13-3—13-7; Ref. I, pp. 260-264)
G. Rocker arms	• Changing bushings • Reaming or honing bushings • Grinding rocker arm to valve contact surface • Changing pushrod contact or adjustment screw (Ref. B, pp. 270-271; Ref. C, pp. 2-21—2-22; Ref. H, pp. 13-26—13-27; Ref. I, p. 263) *Have students practice repairing cylinder heads and component parts on assigned engines. Check students' progress and quality of performance at each step.*

VII. Reassembly

Point out that all parts must be free of dirt and chips before reassembly is attempted. Indicate why it is important to keep parts in order and to return them to the place from which they were removed. Explain and demonstrate how to perform the following:

- Replacing valves (Use oil on stem and face.)
- Replacing valve springs (in correct direction) and valve spring retainers or rotators
- Reinstalling oil seals and/or shields
- Reinstalling valve keys and releasing valve spring compressor (Be sure keys are properly seated.)
- Checking and correcting valve spring installed height
- Rechecking valve protrusion

(Ref. B, pp. 261-274; Ref. C, pp. 2-4—2-21; Ref. H, pp. 13-23—13-25; Ref. I, pp. 263-264)

Have students practice reassembling cylinder heads and component parts.

VIII. Reinstallation

Demonstrate how to reinstall a cylinder head including:

- Preparing engine block for reassembly
- Replacing cylinder head gasket, seals, and O rings
- Using special sealing compounds or oil, if required
- Lifting and placing head on engine block
- Tightening cylinder head bolts (Emphasize the importance of following the correct sequence when tightening a cylinder head.)
- Reinstalling and checking pushrods
- Replacing and adjusting valve bridges

CONTENT OUTLINE | UNDERSTANDINGS AND TEACHING APPROACHES

- Reinstalling and checking fit of roto caps
- Replacing and tightening rocker arms (Explain why valve adjustments must be backed off to prevent damage to the valves when rocker arms are tightened.)
- Adjusting valves
- Replacing and tightening injectors
- Reinstalling valve cover or covers
- Replacing fuel lines, manifold water lines, and accessories
- Filling engine with coolant
- Bleeding high pressure injector lines

(Ref. B, pp. 269-272; Ref. C, pp. 2-1—2-22; Ref. H, pp. 13-25—13-38; Ref. I, p. 64)

Explain and show how to time an engine with an overhead camshaft.

Have students practice reinstalling cylinder heads. Check students for proper work procedures.

Review Discussion

1. Explain how to use the special tools and equipment needed to perform a valve job.
2. Explain how to interpret the results of a wet and dry compression test.
3. What is the first thing to do when starting a valve job?
4. Why is valve seat width important? What should the valve seat width be on a truck diesel engine with no specifications available?
5. Explain how to select valve seat grinding wheels.
6. Why should lifting equipment be used when removing and installing an engine cylinder head?
7. Why would a small scratch in a cylinder head seal surface cause head gasket problems?

Cylinder Heads

8. Why is it important to use a torque wrench when tightening cylinder head bolts or nuts?

9. What is the desirable location of a valve seat on the valve face and how is it obtained?

10. Discuss various methods used to install valve seats securely including dry ice, CO_2, and heating of the cylinder head.

11. Explain how cracked heads are repaired commercially.

12. What can result if the valve adjustment screws are not loosened when the rocker arms are tightened?

13. How does valve guide clearance affect engine life?

14. What safety precautions must be observed when using hydraulic equipment such as lifts, presses, and pullers?

15. Explain how to adjust the valves on a diesel engine.

UNIT 3

ENGINE REMOVAL, DISASSEMBLY, AND CLEANING

OBJECTIVES

The student will be able:

- To drain coolant and oil
- To disconnect engine support equipment
- To remove accessories
- To disconnect engine from vehicle or engine platform
- To lift engine using proper equipment
- To disassemble engine
- To clean engine parts
- To identify worn or defective parts that need to be replaced or repaired

	CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
I.	Engine Removal	Explain why an engine is removed from a vehicle or platform before a major overhaul is attempted.
	A. Preparation	Point out that engine liquids, attachments, and accessories must be drained, removed, or disconnected before the engine can be removed. Show how to prepare an engine for removal including: • Disconnecting battery or starting energy source • Draining cooling and lubricating systems • Removing necessary guards, levers, and shrouds • Removing cooling system connections and/or radiator • Disconnecting all oil, fuel, and air lines

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Disconnecting electrical cables and wires leading from engine to chassis • Disconnecting intake and exhaust tubing and/or piping • Removing any other linkages or parts which would interfere with the engine removal (Ref. H, pp. 12-1—12-5)* Show how to dispose of used oil. Explain why oil should not be poured into a water drain.
B. Removal	Show how to install lifting equipment on a diesel engine. Point out the normal safety procedures to take during the removal process as well as the variations for different types of engines. (Ref. H, pp. 7-5—7-6, 12-1—12-5)
II. Engine Disassembly	Demonstrate how to disassemble a diesel engine and record, on a worksheet, pertinent data which will aid in repair or reassembly. (See Appendix 10.) Include such items as: • Removing cylinder head • Removing fuel injection pump • Locating timing marks and recording position and pattern on engine block worksheet. (See Appendix 10.) • Capping fuel inlets and outlets to prevent entry of dirt • Removing oil pan (Explain why the engine is not turned upside down before the pan is removed.) • Removing oil pump or pumps and piping • Checking markings on connecting rods and recording direction on engine block worksheet • Removing cylinder ridge with a ridge reamer (Ref. H, pp. 16-2—16-3) • Removing connecting rod bolts, nuts, and locking devices (if used)

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*Reference citations are shown on page 109.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES

- Removing connecting rod cap and placing a protective cover over rod bolts or studs (Explain why the rod bolts are covered.) (Ref. H, pp. 16-23—16-24)
- Removing pistons and connecting rods (Point out that on some engines pistons and rods may be removed only after the crankshaft has been taken out. Show how to install rod caps after connecting rod has been removed.)
- Removing starter, generator, compressor, and blower (Explain why blower inlet and outlets should be covered.)
- Removing flywheel and marking it for proper reinstallation
- Removing flywheel bell housing and oil seal flange, if used
- Removing vibration damper and pulleys (Show how to use a puller to prevent damage to parts.) (Ref. H, pp. 7-7—7-8)
- Removing timing case and recording timing lineup points (Ref. C, pp. 2-62—2-63)
- Removing main bearing caps and marking them for reinstallation
- Removing crankshaft using hoist and shaft sling and storing in an upright position (Explain why crankshafts are stored in an upright position or on V blocks.)
- Reinstalling main bearing caps
- Removing camshaft and balance shaft and storing in an upright position
- Removing tappets or cam followers (Explain why it is necessary to keep tappets or cam followers in order.)
- Pulling cylinder sleeves, if required
- Removing all inspection plates and covers including oil galley plugs, water pump filter, and filter housing

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	(Ref. B, pp. 259-313; Ref. C, 2-1—2-63; Ref. H, pp. 13-1, 14-1—14-15)
	Indicate that parts assemblies such as pistons and rods, oil pumps, and rocker arms should not be taken apart until they have been cleaned and are ready for inspection.
	Emphasize the importance of handling parts carefully, especially pistons and bearings, to prevent damage to the shafts and surfaces.
	Point out the variations in the disassembly procedure for different engines.
	Have students practice removing and disassembling their assigned engines and have them record important data on a worksheet. (*See Appendix 10.*)
III. Parts Cleaning	Review the steps for cleaning parts and show any special cleaning procedures needed. Indicate how the cleaned parts should be stored.
	Have students practice cleaning engine parts using the necessary safety precautions. Check to see that all cleaned parts are properly stored. (Ref. H, pp. 9-1—9-8; Ref. I, pp. 245-247)

Review Discussion

1. Discuss the necessary safety precautions to take when lifting heavy equipment.
2. Why is disconnecting the battery or other starting energy source the first step in an engine removal job?
3. Describe the variations necessary when a very large stationary engine is disassembled.
4. Explain why it is important to mark matched parts and record their position and direction for reassembly.
5. Discuss how bearings and pistons should be handled.
6. Discuss various methods and devices used to pull cylinder sleeves.
7. Describe variations in camshaft design and methods of mounting.
8. Discuss various methods of cleaning engine parts.

UNIT 4

ENGINE PARTS INSPECTION

OBJECTIVES

The student will be able:

- To inspect parts for cleanliness, cracks, and damage
- To determine the serviceability of parts
- To determine, by measurement, if parts are within required specifications
- To diagnose reasons for part wear or failure
- To list and order from a parts book all necessary replacement items
- To list all parts requiring repair or service

	CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
I.	Tools and Equipment	Review the use of the following tools prior to the actual inspection: • Micrometers—inside, outside, and depth • Dial bore gauge • Surface gauges • Calipers—inside and outside • Vernier calipers • Small bore gauges • Telescoping gauges • Dial indicators (Ref. B, pp. 41-44; Ref. C, pp. 2-10—2-18, 2-51—2-54; Ref. H, pp. 2-1—2-14; Ref. I, pp. 259-276)* Show how to use the following: • Surface gauges

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*Reference citations shown on page 109.

CONTENT OUTLINE — UNDERSTANDINGS AND TEACHING APPROACHES

- Rod aliner
- Magnaflux equipment

II. Engine Block

Show how to inspect an engine block including the following:

- All surfaces for cracks and erosion
- Block to cylinder head contact surface for cracks, warpage, waterhole erosion, and stud condition
- Core plugs for tightness and condition
- Cylinder bore for wear, taper, and being out of round
- Cylinder block sleeve bore for counterbore dimension, surface finish, and surface seal
- Main bearing saddles and caps for alinement, dimension, cracks, being out of round, and stud condition
- Camshaft bearings and/or bores for wear and alinement
- Balance shaft bearings and bores for wear
- Oil galley for dirt and obstructions

(Ref. B, pp. 309-315; Ref. C, pp. 2-23—2-30; Ref. E, pp. 31-38; Ref. H, 16-1—16-10)

During the inspection procedure, explain how to determine the serviceability of each part. Also, point out the reasons for any abnormal wear or failure of a part.

Explain how to use an engine worksheet to record the findings of an inspection. (See Appendix 9)

Show how to use a parts book to compile a list of required replacement items.

Discuss the different metals used in the manufacture of engine blocks.

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

Explain the various types of cylinder and/or sleeve designs used on diesel engines including:

- Wet
- Dry
- Cast-in
- Built-in cooling jacket

(Ref. C, pp. 2-25—2-29; Ref. E. pp. 33-39; Ref. F, pp. 122-128; Ref. I, pp. 152-154, 264-267)

Have students inspect blocks on assigned engines and record their findings on an engine worksheet.

III. Cylinder Sleeves or Liners

Review with students the inspection of cylinder bores and the desired surface finish they should have.

Demonstrate how to inspect sleeves for:

- Cracks
- Pitmarks
- Coolant deposits
- Sealing surface condition
- Discoloration due to hot spots

(Ref. C, pp. 2-25—2-29)

Provide a number of sleeves and ask students to identify those sleeves that should be rejected and to give reasons for their rejection.

Have students inspect sleeves on assigned engines and record their findings on an engine worksheet.

IV. Pistons

Show how to remove a piston from a connecting rod and the rings from a piston.

Show students how to handle piston rings to avoid injury to themselves and damage to the rings.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	Point out the importance of the relationship of the piston to the connecting rod and to record this information for reassembly. Demonstrate how to inspect pistons including the condition of the following: • Piston head • Scuff band (if used) • Ring lands • Ring grooves (if worn, replace) • Piston skirts • Piston pin bore and bosses • Oil ring returns • Oil cooling fins and canals, if used (Ref. B, pp. 286-299; Ref. C, pp. 2-20—2-43; Ref. F, pp. 129-136; Ref. I, pp. 274-277)
V. Piston Pin	Show and explain the various methods used to prevent the piston pin from contacting the cylinder wall including: • Block rings • Lock bits • Press fit • Bolting • Stop plugs (Ref. B, pp. 295-300; Ref. C, pp. 2-44—2-45; Ref. F, pp. 148-152; Ref. H. pp. 16-13—16-20) Demonstrate how to inspect piston pins for wear, discoloration, and obstructed lubrication holes.
VI. Piston Rings	Explain and show examples of the various types, designs, functions, and materials used in the manufacture of piston rings.

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

Demonstrate how to inspect piston rings for

- Side wear and clearance
- End gap
- Back clearance

(Ref. B, pp. 298-300; Ref. C, pp. 2-30—2-44; Ref. F, 136-145; Ref. H, pp. 16-20—16-23)

Have students practice removing pistons from connecting rods and rings from pistons. Have students inspect pistons, rings, and pins on assigned engines and record their findings on an engine worksheet.

Demonstrate how to reinstall piston rings.

Have students practice reinstalling piston rings.

VII. Connecting Rods

Describe the various types and designs of connecting rods. (Ref. I, pp. 174-176)

Show faulty connecting rods and explain why they should be rejected.

Demonstrate how to inspect a connecting rod for

- Alinement
- Cracks
- Pin Bore or bushing wear
- Discoloration and taper of the journal (big end)

(Ref. B, pp. 286-291; Ref. C, pp. 2-45—2-48; Ref. F, pp. 146-152; Ref. H, pp. 16-24—16-30)

Have students inspect connecting rods on assigned engines and record their findings on an engine worksheet.

VIII. Crankshaft

Explain and show examples of the various types, designs, functions, and materials used in the manufacture of crankshafts. (Ref. I, pp. 170-174)

Explain the reasons why crankshafts fail.

Show how to inspect a crankshaft for:

- Cracks (magnetic)
- Obstructed oil passages
- Journal wear
- Being out of round and tapered
- Keyway wear
- Surface condition
- Fillet radius
- Oil seal surface condition
- Alinement

(Ref. B, pp. 302-308; Ref. C, pp. 2-48—2-54; Ref. F, pp. 153-158; Ref. I, pp. 247-254)

IX. Counterweights

Explain and show examples of the various designs and functions of removable counterweights.

Explain why counterweights must be marked for position before being removed. (Ref. F, pp. 156-157)

Have students inspect crankshafts and counterweights on assigned engines and record their findings on an engine worksheet.

X. Flywheel

Describe and show examples of various types, designs, function, and composition of flywheels.

Demonstrate how to handle and inspect various types of flywheels including the condition of:

- Crankshaft contact surface
- Clutch surface
- Ring gear
- Dowel holes
- Alinement

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	Have students inspect flywheels on assigned engines and record their findings on an engine worksheet.
XI. Vibration Dampers and Pulleys	Explain and show examples of various types and functions of vibration dampers.
	Demonstrate how to inspect vibration dampers including the following types: • Rubber bonded • Spring controlled • Fluid controlled • Friction mounted
	Discuss the various types of pulleys and show how to inspect them for wear, alinement, cracks, and being out of round. (Ref. C, p. 2-55; Ref. F, pp. 158-160)
	Have students inspect pulleys and vibration dampers on assigned engines and record their findings on an engine worksheet.
XII. Bearings	Explain the reasons for bearing failures. Describe and show examples of various types, designs, function, and materials used in the manufacture of bearings.
	Demonstrate how to inspect the following types of bearings: • Ball • Roller • Needle • Friction used for rod, main, bushing, and thrust bearings
	(Ref. B, pp. 302-306; Ref. C, pp. 2-47—2-61; Ref. F, pp. 162-171; Ref. H, pp. 10-1—10-14)
	Have students inspect all bearings on assigned engines, following manufacturer's specifications, and record their findings on an engine worksheet.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
XIII. Dynamic Seals	Explain and show examples of the various types, designs, function, and materials used in the manufacture of dynamic seals. Demonstrate how to inspect various types of dynamic seals including: • Lip • Exclusion • Clearance • Packing (Ref. B, p. 307; Ref. H, pp. 4-9—4-12) *Have students inspect dynamic seals on assigned engines and record their findings on an engine worksheet.*
XIV. Timing Gears and Chains	Describe and show examples of the various types, designs, and functions of timing chains and gears. Show how to handle and inspect the following timing devices: • Gear to gear • Gear to chain to gear • Sprocket to belt to sprocket (Ref. B, pp. 180-182; Ref. C, pp. 2-62—2-63; Ref. H, pp. 15-1—15-10; Ref. I, pp. 269-270) *Have students inspect timing devices on assigned engines and record their findings on an engine worksheet.*
XV. Camshaft	Explain and show examples of the various types, designs, and functions of camshafts. Demonstrate how to inspect various types of camshafts for: • Alinement • Cracks (magnetic inspection) • Cam lobe lift and condition

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Fuel cam lobe condition
- Bearing journal wear, taper, and being out of round
- Tachometer and/or injection pump drive gear condition

(Ref. B, pp. 278-280; Ref. C, pp. 2-16—2-19; Ref. H, pp. 15-11—15-15; Ref. I, pp. 268-269)

Explain how to store a camshaft to prevent damage.

Have students inspect camshafts on assigned engines and record their findings on an engine worksheet.

XVI. Balance Shafts and Balancers

Describe and show various types, designs, and functions of balancers and balance shafts. Demonstrate how to inspect a balance shaft for:

- Alinement
- Main journal wear
- Bearing wear
- Weight mounting for wear
- Broken balance weight mounting springs
- Balancer gear backlash

(Ref. C, pp. 2-55—2-56; Ref. F, p. 155)

Have students inspect balancers and/or balance shaft on assigned engines and record their findings on an engine worksheet.

XVII. Tappets (lifters) and Cam Followers

Explain and show examples of the various types and function of tappets (lifters) and cam followers.

Explain why parts cannot be interchanged between individual units.

Point out that units must be stored so they can be returned to the original bore.

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

Demonstrate how to inspect the following:

- Solid tappets for cracks and scoring, proper bore diameter, camshaft contact surface condition, and pushrod or valve contact surface condition
- Hydraulic lifters for cleanliness, proper bore diameter, lifter body condition, plunger condition, ball and spring, camshaft contact area, pushrod contact condition, and leak down rate
- Cam followers for scored body, worn roller, worn bushing and pin, and pushrod contact surface condition

(Ref. B, pp. 281-282; Ref. C, pp. 2-19—2-20; Ref. F, pp. 179-180; Ref. H, pp. 13-27—13-31)

Have students inspect tappets, lifters, and/or cam followers on assigned engines and record their findings on an engine worksheet.

XVIII. Pushrod

Explain and show examples of the various types and functions of pushrods used in diesel engines. Point out how pushrods on large engines are manufactured.

Demonstrate how to inspect the different types of pushrods for:

- Length
- Alinement
- Condition of lubrication passages
- Pushrod ends and decompression ring or notch

(Ref. C, p. 2-20; Ref. H, p. 13-27; Ref. I, p. 263)

Explain why pushrods must be kept in order so they may be returned to their original location.

Have students inspect pushrods on assigned engines and record their findings on an engine worksheet.

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

XIX. Oil Pumps

Explain the function and operation of oil pumps including the following types:

- Piston
- Gear
- Vane
- Rotor

Show how to mark the gears on gear pumps before removal to facilitate reassembly.

Demonstrate how to inspect various types of oil pumps including checking the following:

- Pump end plate condition
- Housing condition
- Gear to gear clearance
- Vane wear
- Gear or rotor to housing clearance
- Gear or rotor to cover clearance
- Shaft bushing condition
- Pump shaft wear
- Pump piston and cylinder wear
- Pressure relief valve and spring condition

(Ref. G. pp. 99-191; Ref. C, pp. 7-2—7-4)

Have students inspect oil pumps on assigned engines and record the information on an engine worksheet.

Have students practice disassembling engines, cleaning components, inspecting and determining the serviceability of parts, and listing parts that need replacing. Students should acquire the proficiency necessary for an entry mechanic.

Engine Parts Inspection

Review Discussion

1. Discuss how to use the various inspection tools.
2. Explain why different kinds of metals are used in the manufacture of engine blocks.
3. Explain why cylinder sleeves are used on diesel engines.
4. Discuss the advantages and disadvantages of various piston designs.
5. Explain the different methods used to fasten pistons to connecting rods.
6. Discuss the various types and functions of piston rings.
7. Explain how engine life can be prolonged by careful and periodic inspection of connecting rods.
8. Explain how to inspect a crankshaft.
9. Why is it important to mark counterweights before they are removed from the crankshaft?
10. Explain the term kenetic energy in relation to the flywheel.
11. Discuss torsional vibrations in relation to the crankshaft.
12. Discuss why different kinds of metals are used in the construction of friction bearings.
13. What is meant by bearing crush?
14. Explain how to handle and inspect roller bearings.
15. Explain how a gear tooth is so designed as to reduce friction.
16. Discuss the function of the different parts of a camshaft.
17. Why cannot hydraulic valve lifter parts be interchanged?
18. Why must a valve lifter be returned to the same location?
19. Explain how pushrods are repaired on large engines.
20. Discuss how the oil pump prolongs engine life.

UNIT 5

ENGINE PARTS REPAIR, REASSEMBLY, AND REINSTALLATION

OBJECTIVES

The student will be able:

- To repair and replace individual engine parts
- To reassemble engine parts
- To replace defective parts
- To check parts for correct assembly
- To operate machines used in the repair of engine parts
- To reinstall engine into a vehicle or engine bed
- To prepare engine for starting
- To start engine and check all systems for operation
- To perform the recommended engine run-in procedures
- To check engine performance using a dynamometer

	CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
I.	Tools and Equipment	Explain and demonstrate, prior to and during engine overhaul and repair, the operation and use of the following tools and equipment: • Engine block resurfacing machine • Cylinder boring bar • Line boring bar • Cylinder hone • Connecting rod aliner • Bushing installer • Sleeve installer and puller

- Gear and bearing puller
- Piston pin remover/installer
- Piston ring groove cutter
- Piston knurling tool
- Bushing honing machine
- Piston ring compressor
- Bearing and seal installing tool

Schedule students for practice on the above tools prior to using them on live engines.

Explain why it is important to follow manufacturers' maintenance procedures and torque specifications when overhauling engines.

Explain why all SAE grade 8 bolts should be replaced with new ones during reassembly.

Caution students to turn all moving parts during the tightening process in order to detect any binding and to prevent damage to parts.

II. Engine Block

Demonstrate how to repair and reassemble an engine block including:

- Resurfacing cylinder head contact surface
- Line boring main bearing saddles (Use manufacturer's shop manual to determine maximum limits of stock removal.)
- Deglazing cylinders
- Reboring cylinders and sleeves and/or sleeve bore and counterbore
- Honing cylinders and sleeves (Point out the desired surface finish and pattern.)
- Checking piston fit with micrometer, dial bore gauge, feeler gauge, and inch-pound scale
- Recleaning block after machine operation

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Removing and replacing camshaft bushings including the lining up of oil holes, using a bushing installer, and line boring of semifinish bushings
- Reinstalling main bearings including the lining up of oil holes and locating tabs or pins, checking bearing crush, line boring of semifinish bearings, and checking for correct placement of upper and lower bearing halves
- Changing core plugs
- Reinstalling oil galley plugs
- Reinstalling cylinder head studs
- Removing and replacing cylinder liners including proper liner protrusion. installing wet liner seals and/or "O" rings, and using special sealing or lubrication compound (Explain how to keep liners in position with holddown clamps or washers.)
- Reinstalling end plates, if used
- Reinstalling and checking direction of oil spray nozzles

(Ref. B, pp. 114-125, 283-315; Ref. C, pp. 2-23—2-63; Ref. H, p. 18-1; Ref. I, pp. 264-271)*

Explain why cleanliness is so important during the entire repair and reassembly operation. Show how to clean and oil machined surfaces.

Have students repair and reassemble engine blocks on assigned engines. Inspect each student's work to see if correct work procedures are being followed and to make suggestions and corrections, if any are needed.

III. Camshaft

Demonstrate how to reinstall a camshaft including:

- Reinstalling timing gear cam
- Putting oil on cam bearings

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*Reference citations are shown on page 109.

- Replacing valve tappets before camshaft is installed, if required
- Reinstalling camshaft
- Checking end play and bearing clearance
- Checking camshaft timing gear run-out

(Ref. B, pp. 279-281; Ref. C, p. 2-53; Ref. H, pp. 15-13—15-16; Ref. I, pp. 268-270)

Have students reinstall camshafts on assigned engines following manufacturers' procedures and specifications. Check each student's work for correct procedures and quality of work.

IV. Crankshaft

Explain the various procedures used to recondition crankshafts including:

- Grinding
- Plating
- Welding
- Straightening

Demonstrate how to reinstall a crankshaft including:

- Reinstalling timing gear
- Removing burrs around oil hole, if shaft has been reground
- Removing any scratches and micrometer marks on journals
- Recleaning journals and oil holes
- Removing main caps
- Alining main bearing oil holes with block
- Placing clean engine oil on bearings
- Lifting crankshaft with hoist and shaft sling and lowering slowly and carefully onto main bearings (Be sure to lineup the timing marks.)

- Replacing main bearing caps and putting clean oil on bearings (Point out the necessity of liningup the cap markings.)
- Hand tightening main bearings one at a time
- Checking crankshaft for binding
- Tightening main bearing caps to 75 percent of final torque
- Checking shaft end play
- Checking main bearing oil clearance with a plastic gauge
- Checking timing gear backlash
- Tightening main bearing caps to final torque
- Safetying main bearing caps, bolts, or nuts, if required

(Ref. B, pp. 302-308; Ref. C, 2-45—2-46; Ref. D, pp. 174-176; Ref. E, pp. 56-62; Ref. I, pp. 270-271)

Point out that when split main seals are used, the shaft should be removed after the main bearing oil clearance has been checked in order to install the seals.

Indicate that on some engines the pistons and rods are installed before final crankshaft installation.

Have students reinstall crankshafts on assigned engines following manufacturers' procedures and specifications. Insist on cleanliness when handling bearings.

V. Connecting Rod

Demonstrate how to repair and reassemble a connecting rod including:

- Installing piston pin bushings
- Fitting piston pin bushings to pin
- Alining correcting rod

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Checking journal bearing fit in rod • Checking connecting rod weight
	(Ref. B, pp. 284-295; Ref. C, pp. 2-30—2-47; Ref. E, pp. 51-55; Ref. I, pp. 270-274)
	Indicate that some engine manufacturers recommend using new rod bolts when engines are rebuilt.
	Have students repair and reassemble connecting rods on assigned engines. Inspect each student's work for correct procedures and quality of work.
VI. Pistons, Rings, and Pins	Demonstrate how to repair and reassemble pistons, rings, and pins including:
	• Knurling pistons • Removing scratches and scuff marks from piston • Reconditioning worn piston ring grooves • Checking to see that all pistons are of the same weight and design • Attaching pistons to connecting rods including heating of piston, reinstalling and securing piston pin, and following lineup marks on the piston and rod • Reinstalling piston rings, if not previously done • Rechecking fit of piston rings and spacing gaps • Putting oil on pistons • Using ring compressor • Protecting threads on rod bolts • Reinstalling upper half of rod bearings • Alining oil holes • Inserting piston and connecting rod into cylinder and alining rod with journal

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Putting clean oil on bearings and connecting rod caps
- Replacing and tightening rod caps (Check for any binding.)
- Checking height of piston at TDC
- Checking rod bearing clearance
- Safetying rod bolts or nuts

(Ref. B, pp. 114-124; 298-300; Ref. C, pp. 2-30—2-47; Ref. D, pp. 169-173; Ref. E, pp. 41-58)

Demonstrate how to check piston and rod alinement by using a feeler gauge.

Explain how the piston skirt functions as bearing.

Explain how the shape of the piston head affects combustion.

Indicate that on some engines the pistons and sleeves are installed as a unit (preassembled).

Have students repair and reinstall pistons, rings, and connecting rods on assigned engines following manufacturers' specifications. Check each student's performance for accuracy and cleanliness.

VII. Counterweights

Explain and show how to reinstall crankshaft counterweights including:

- Replacing weights to the premarked position
- Safetying weights
- Checking clearance between moving weights and other engine parts

(Ref. D, pp. 175-176; Ref. E, pp. 60-62)

Have students attach counterweights to crankshafts of assigned engines.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
VIII. Balance Shafts and Balancers	Discuss and show how to repair and reinstall balance shafts and balancers including: • Checking bearing fits • Changing bearings • Replacing shafts or balancers • Timing shafts or balancers • Reinstalling balance weights on shafts or balancers (Ref. C, pp. 2-54—2-56; Ref. E, pp. 307-321) *Have students repair, reinstall, and time balance shafts and balancers on assigned engines.*
IX. Timing Gears, Chains, Gear Train, Gear Train Cover, and Vibration Damper	Demonstrate how to reassemble the following engine parts: • Auxiliary shafts and drives • Idler gears • Timing chains • Injection pump drives • Gear train cover Show how to perform the following: • Setting timing gears and chains • Adjusting gears or chain backlash • Checking bearing fit • Checking shaft end play • Safetying bolts • Adjusting chain tighteners • Alining gears and chains • Reinstalling oil slinger, if used

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	- Checking condition of oil seal (change if necessary) - Alining cover and engine block surfaces - Reinstalling vibration damper flange, damper, and attached pulleys - Checking damper and/or damper runout
	(Ref. D, pp. 280-282; Ref. C, pp. 2-3—2-63; Ref. E, pp. 318-321)
	Have students repair and reinstall timing gears, chains, and gear trains on assigned engines. Check each student's work for correct procedures and quality of work.
X. Bell Housing, Flywheel, and Rear Main Seal	Explain and show how to repair and reinstall the following:
	- Rear main seal including changing seals, alining cover, correcting damaged seal surfaces on shafts, and tightening seal and cover - Bell housing including checking and correcting concentricity of transmission flange to flywheel or crankshaft, reinstalling rear camshaft covers or gaskets, tightening housing bolts, and safetying housing bolts - Flywheel including machining of clutch surface, changing starter ring gear, lifting and reinstalling flywheel following lineup marks, tightening and safetying flywheel bolts, changing pilot bearings, checking flywheel runout, and reinstalling clutch disk and pressure plate
	(Ref. C, pp. 2-48—2-62; Ref. D, pp. 176-177; Ref. E, pp. 74-82)
	Have students repair and reinstall flywheels, bell housings, and rear main seals on assigned engines. Check each student's work for correct performance and quality of work.

CONTENT OUTLINE — UNDERSTANDINGS AND TEACHING APPROACHES

XI. Oil Pumps

Show how to repair, reassemble, and reinstall oil pumps including:

- Changing bushings
- Lapping or grinding pump end plate, bypass valve seats, and end plate surface of housing
- Reinstalling (new, if required) gears, rotors, vanes, pistons, and shafts
- Rechecking clearances
- Selecting gaskets for proper gear end clearance
- Reinstalling pump end plate, bypass valve, oil pickup tube, pump to engine, and oil lines

(Ref. C, pp. 7-1—7-8)

Have students repair, reassemble, and reinstall oil pumps on assigned engines. Check each student's work after pump reassembly and reinstallation for correct procedures and quality of work.

XII. Oil Pan and Balancers

Demonstrate how to repair and reinstall balancers and oil pans including:

- Changing balancer bearings
- Timing balancer gears
- Timing balancer to engine
- Fastening balancer to engine
- Rechecking all internal bolts and units for tightness, safetying, and cleanliness (Explain why this step is so important to do prior to fastening the oil pan and closing the crank case.)
- Reinstalling oil screen, oil pan and sump, and gasket

(Ref. C, pp. 2-55, 7-11—7-16)

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

Have students repair and replace oil pans and balancers on their assigned engines. Check each student's work carefully before the oil pan is reinstalled.

XIII. Tappets, Hydraulic Lifters, and Cam Followers

Demonstrate how to repair and reinstall tappets, hydraulic lifters, and cam followers including:

- Grinding camshaft contact surface on tappets and lifters, if required
- Changing worn cam follower parts
- Disassembling, cleaning, and reassembling hydraulic lifters
- Checking hydraulic lifter leak-down rate

(Ref. B, pp. 133-135; Ref. C, pp. 2-19—2-20; Ref. D, pp. 186-187; Ref. E, pp. 87-95)

Explain why parts must not be interchanged between units and why lifters must be returned to their original bore.

Have students repair and reinstall tappets, hydraulic lifters, and cam followers on their assigned engines.

XIV. Cylinder Heads

Review the procedures for reinstalling a cylinder head. See Unit 2, Cylinder Heads.

Have students reinstall cylinder heads on their assigned engines.

XV. Engine Accessories and Attachments

Explain and demonstrate how to reinstall the following engine attachments:

- Intake and exhaust manifolds
- Fuel injection pump including timing, alining, and bleeding of air
- Oil and fuel filters
- Oil manifolds and coolers
- Water pumps
- Starters or starting devices

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Generators
- Compressors
- Vacuum pumps
- Turbochargers or blowers

(Ref. E, pp. 196-282)

Have students reinstall engine accessories and attachments on assigned engines. Check each student's work for correct procedures and quality of work.

XVI. Reinstalling Engine into Vehicle

Explain and demonstrate the following engine reinstallation procedures:

- Removing engine from work stand
- Lifting engine into vehicle or engine bed
- Alining engine
- Tightening engine mounts
- Reinstalling cooling system
- Connecting intake, exhaust, electrical, and lubrication systems, and fuel and air lines
- Priming injection and lubrication systems
- Filling cooling system

(Ref. E, pp. 325-336)

Have students reinstall their assigned engines into vehicles and prepare them for starting.

XVII. Engine Starting, Running-in and Testing

Discuss the procedures for starting, running-in, and testing an engine.

Explain and demonstrate how to start an engine including:

- Making sure engine is ready for starting
- Preparing for a possible emergency shutdown

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Connecting starting energy source
- Starting pony engine, if used
- Starting engine and checking immediately the oil pressure, r.p.m., coolant circulation, and for oil and coolant leaks

(Ref. E, pp. 337-354)

Demonstrate the run-in procedure emphasizing:

- Proper r.p.m. and load
- Run-in time
- Engine temperature
- Engine oil pressure and/or temperature
- Correct idle r.p.m.
- Proper maximum no load r.p.m.

(Ref. C, pp. 2-63, 12-3)

Explain the advantages of testing an engine on a dynamometer.

After the run-in is completed, and, if a dynamometer is available, show how to use it to check the following:

- Maximum torque output
- Maximum horsepower
- Exhaust gas temperatures
- Engine temperature
- Fuel consumption

(Ref. C, pp. 11-5—11-14; Ref. E, pp. 339-343, 375-390; Ref. H, pp. 18-1—18-8)

Have students start, run-in, and test their assigned engines. Check each engine carefully before it is started. Have students repair, reassemble, reinstall, start, and test diesel engines until they acquire the proficiency necessary for an entry mechanic.

Engine Parts Repair, Reassembly, and Reinstallation

Review Discussion

1. List and explain the different methods used for reboring cylinders.
2. List the different cylinder designs and discuss the sealing and installation of sleeves.
3. Explain the importance of making a detailed inspection of a camshaft.
4. Discuss the importance of cleanliness when handling bearings and shafts.
5. Explain why only one thrust bearing is used on any shaft.
6. Explain how to prepare a crankshaft for installation.
7. Discuss the dangers involved when working on heavy shafts and turning them.
8. List and explain the operation of the various types of combustion chambers used in diesel engines.
9. Explain how very large diesel engines are reassembled.
10. Explain why most diesel engine pistons are oil cooled.
11. Determine the distance traveled by a piston skirt in one hour when the engine is turning at 3600 r.p.m. and a piston stroke of 6 inches.
12. Discuss the operation and design of the GM crosshead type piston.
13. Why is it important that engine balancers are timed properly?
14. List and explain the various methods used to time and drive various engine parts.
15. Why is it necessary to prime the lubrication system on most engines after they have been rebuilt?
16. Why is it necessary to prime the fuel system?
17. Explain why it is important that flywheels have no runout.
18. Why is it necessary to be prepared for an emergency shutdown when starting diesel engines?
19. Explain the advantage of using a dynamometer for engine run-in and testing.
20. Discuss the importance of having cooling water in the engine during the starting, especially on engines equipped with oil sleeves.

UNIT 6

ENGINE ACCESSORIES

OBJECTIVES

The student will be able:

- To check, service, and repair the component parts of the air induction system
- To check, service, and repair blowers and turbochargers
- To identify the parts of the cooling system and describe their function
- To check, service, and repair the component parts of the cooling system
- To list the parts of the lubrication system and describe their function
- To check, service, and repair the component parts of the lubricating system
- To describe the operation of various starting systems
- To check, service, and repair the component parts of the starting system
- To check, service, and repair fuel filters, tanks, and lines
- To check the operation of injectors and injection pumps

	CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
I.	Air Induction System	Discuss the function and operation of the various parts of the air induction system including the: • Manifolds • Air ducts and emergency shut off • Air cleaner filters • Loading pistons

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Blowers (superchargers)
- Turbochargers
- After coolers
- Cold start preheaters

(Ref. C, pp. 6-1—6-24; Ref. D, pp. 393-397; Ref. E, pp. 244-259; Ref. I, pp. 117-130, 201-205)*

A. Manifolds

Explain and show how to service manifolds including:

- Removing, cleaning, and inspecting
- Machining gasket surfaces
- Installing swirl deflectors
- Reinstalling manifolds

(Ref. E, p. 250)

Have students service and reinstall manifolds on their assigned engines.

B. Air ducts and emergency shutoffs

Explain and demonstrate how to service and repair air ducts and emergency shutoffs including:

- Inspecting air ducts for leaks
- Reinstalling air ducts
- Alining air ducts
- Checking operation of emergency shutoff
- Adjusting emergency shutoff

Have students service, repair, and reinstall air ducts and emergency shutoffs on their assigned engines.

C. Air cleaners

Explain the operation of different types of air cleaners including:

- Dry

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*Reference citations are shown on page 109.

CONTENT OUTLINE | UNDERSTANDINGS AND TEACHING APPROACHES

- Oil bath
- Centrifugal (cyclone)
- Self-cleaning

(Ref. C, pp. 6-1—6-9; Ref. D, pp. 393-397; Ref. E, pp. 244-250; Ref. I, pp. 201-205)

Explain and show how to service air cleaners including:

- Changing filter element and/or cleaning agent
- Cleaning filter
- Changing oil
- Checking filter operation
- Checking for restrictions

(Ref. I, pp. 287-293)

Have students practice servicing air cleaners. Rotate students from one type to another in order that all students will have experience servicing different types of air cleaners.

D. Air charging piston and crankcase scavenging

Explain and demonstrate how to service the charging piston and crankcase scavenging unit including:

- Checking valve operation
- Checking scavenging pressure
- Cleaning ports
- Changing parts

(Ref. C, pp. 1-16—1-18; Ref. I, pp. 120-121)

Have students service the air charging piston and crankcase scavenging units on their assigned engines. If a piston charged engine is not available, a small two stroke cycle engine may be used for demonstration and student practice.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
E. Superchargers	Discuss the various types, designs, and operation of superchargers.
1. Roots type blowers	Explain and show how to service and repair a Roots type blower including: • Removing and disassembling blower • Inspecting and cleaning blower parts • Removing scratches and nicks • Changing blower seals and bearings • Reassembling blower and adjusting rotor clearances • Timing of blower to engine • Reinstalling blower (Ref. C, pp. 6-13—6-22; Ref. D, pp. 195-198; Ref. E, pp. 250-259; Ref. I, pp. 281-283) Point out the precautions to take when working on engines with blowers, such as covering intake, keeping fingers away from blower intake, and having no loose clothing or long hair that could catch in the unit. *Have students practice servicing and repairing Roots type blowers. This can be done on practice units or on assigned engines that use this type of blower.*
2. Centrifugal blower	Demonstrate how to service and repair centrifugal blowers including: • Removing blower • Checking impeller clearances • Disassembling blower • Cleaning and checking blower for wear, runout, balance, and cracks • Reassembling parts • Reinstalling blower

(Ref. C, p. 6-14; Ref. D, pp. 196-199; Ref. E, pp. 251-252; Ref. I, pp. 122-124)

Have students practice servicing and repairing centrifugal blowers. Use a mockup or an engine timing case with a centrifugal blower for practice.

3. Turbochargers

Demonstrate how to service and repair turbochargers including:

- Checking operation and lubrication
- Checking turbine housing for cracks
- Cleaning turbine and compressor wheels
- Removing unit from engine
- Checking bearing radial clearance and shaft end play
- Disassembling turbocharger
- Cleaning and replacing worn parts
- Reassembling turbocharger
- Reinstalling turbocharger
- Prelubricating turbocharger after installation

(Ref. C, pp. 6-14—6-22; Ref. D, pp. 199-205; Ref. I, pp. 122-128, 283)

Explain why the balance and allowed tolerances are critical on centrifugal blowers and turbochargers.

Have students service and repair turbochargers on their assigned engines. Have students practice servicing turbochargers on practice units first.

F. Aftercoolers and precoolers

Explain and show how to service and repair aftercoolers and precoolers including:

- Removing and cleaning parts

- Reinstalling coolers and checking for leaks

(Ref. I, pp. 128-129)

Have students service aftercoolers and precoolers on their assigned engines.

II. Cooling System

Discuss the operation and function of the component parts of the cooling system including:

- Water pumps
- Radiators
- Radiator shutters and shutter stats
- Fans and belts
- Heat exchangers
- Thermostats and bypasses
- Pressure caps
- Water filters and conditioners

Explain and show how to service and repair component parts of the cooling system including:

- Checking for leaks
- Rebuilding and replacing water pumps
- Adjusting and checking radiator shutter operation
- Replacing hoses
- Cleaning cooling system
- Checking pressure caps
- Checking and changing thermostats
- Checking filters and conditioners
- Adjusting belts

(Ref. C, pp. 8-1—8-16; Ref. D, p. 376; Ref. E, pp. 218-242; Ref. I, pp. 185-199)

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

Discuss the maintenance of the cooling system on very large diesel engines.

Have students service and repair the component parts of the cooling system on their assigned engines.

III. Exhaust System

Discuss the operation and function of the component parts of the exhaust system including:

- Manifolds and exhaust piping
- Mufflers and spark arrestors
- Exhaust temperature indicators (pyrometers)
- Exhaust analyzers
- Heat recovery systems (used on large engines)

(Ref. C, pp. 6-12—6-13; Ref. D, pp. 397-401; Ref. E, pp. 261-283; Ref. I, pp. 179-184)

Show how to use test equipment to check the operation of the exhaust system.

Explain and show how to service and repair component parts of the exhaust system including:

- Changing manifolds, exhaust piping, gaskets, and mufflers
- Cleaning manifolds (including water cooled manifolds)
- Cleaning spark arrestors
- Checking exhaust with temperature indicators and analyzers
- Diagnose exhaust system problems

(Ref. I, pp. 292-293)

Have students service and repair the component parts of the exhaust system and to conduct operational tests on their assigned engines.

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

IV. Lubrication System

Discuss the operation and function of the component parts of the lubrication system including:

- Oil pumps, pickups, and screens
- Pressure regulators and bypasses
- Oil filters
- Piston cooling nozzles
- Oil cooler
- Cylinder lubrication (used on large engines)

(Ref. C, pp. 7-1—7-19; Ref. D, pp. 251-264; Ref. E, pp. 196-217; Ref. I, pp. 209-220)

Discuss lubricants including types, qualities, grades, selection, and handling.

Explain how lubricants are reconditioned.

Explain and show how to service and repair component parts of the lubrication system including:

- Changing filters and oil
- Checking oil level, condition, and pressure
- Adjusting oil pressure
- Replacing oil pump and cooler
- Priming lubrication system

Explain why it is necessary to prime the lubricating system on large diesel engines.

Have students service and repair the component parts of the lubrication system on their assigned engines.

V. Electrical System

Use the Automotive Industries Occupations Electrical Services published by the State Education Department for the following items:

CONTENT OUTLINE | UNDERSTANDINGS AND TEACHING APPROACHES

- *Fundamentals of automotive electricity*
- *Storage batteries*
- *Charging systems*

Explain the operation, service, and adjustments of the following:

- Series-parallel battery switching solenoids
- Fuel shutoff solenoids
- Magnetos
- Electric fuel pumps

Have students practice servicing and adjusting the component parts of the electrical system on their assigned engines.

VI. Starting Systems

A. Electric starters

Use the publication, Electrical Services, for information on electric starters.

Explain and demonstrate how to service and repair the component parts of electric starting units.

Have students practice servicing and repairing the component parts of electric starting units.

B. Air starters

Discuss the design and operation of the air starting system.

Explain and show how to service and repair the component parts of an air starting system including:

- Checking system pressure
- Checking overpressure safety valve operation
- Draining water from system
- Servicing lubricator
- Removing and reinstalling air starters

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Rebuilding air starters • Rebuilding air compressors (Ref. D, pp. 401-404; Ref. I, pp. 223-225) *Have students practice maintaining and repairing the component parts of air starter units.*
C. Direct-air starting (large engines)	Discuss the design and operation of the direct-air starting systems. Explain and demonstrate how to service and repair the component parts of a direct-air starting system including all control valves. (Ref. D, p. 401; Ref. E, pp. 284-296; Ref. I, pp. 223-224) *Have students practice servicing and repairing the component parts of a direct-air starting system. Because the direct-air starting system is used on very large engines, a mockup of the system may be used for practice.*
D. Hydro-starters	Discuss the design and operation of the hydro-starting system. Explain and demonstrate how to service and repair the component parts of a hydro-starting system including: • Precharging system with nitrogen • Hand-charging system • Maintaining charging pumps and control valves • Repairing starting motor (Ref. I, p. 223) Point out the precautions that need to be followed when working on high pressure hydraulic systems. *Have students practice servicing and repairing the component parts of the hydro-starting systems.*

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
E. Pony engine starters	Explain and show how to service and repair pony engines including: • Changing spark plugs, points, and condenser • Checking magnetos • Timing distributors • Adjusting carburetors • Adjusting drive clutches • Removing and replacing pony engine • Starting and operating pony engine (Ref. E, pp. 287-288; Ref. I, p. 122) *Have students practice servicing and replacing pony engines. If pony engines are not available, use other small gasoline engines for practice.*
VII. Basic Fuel System	Discuss the operation of the main component parts of the basic fuel system including: • Tanks • Piping • Transfer pumps • Filters • Injectors and pumps (Ref. C, 5-1—5-8; Ref. D, pp. 206-239; Ref. E, pp. 155-172; Ref. I, pp. 25-31, 53-58) Explain diesel fuel grades and their uses. Explain and show how to service and repair the component parts of the fuel system including: • Draining fuel tanks • Repairing fuel tanks (Point out the safety precautions to take when repairing fuel tanks.)

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Flaring, bending, and routing tubing
- Checking and servicing transfer pumps
- Servicing fuel filters
- Checking and timing injectors
- Checking, alining, and timing injection pumps
- Repairing high pressure lines
- Checking fuel pressure lines

(Ref. C, pp. 5-34—5-36; Ref. I, pp. 257-293)

Explain how a high pressure fuel discharge can cause injury and blood poisoning.

Have students service the injectors on their assigned engines. Do not include the rebuilding of injectors, injection pumps, or governors as these will be covered in Unit 8, Injection Systems and Controls.

Review Discussion

1. Discuss the importance of the air induction system for proper engine operation.
2. Why are emergency shutoffs important on diesel engines?
3. What are the advantages of the turbocharger over other air-charging devices?
4. List the main parts of the two types of cooling systems in common use and explain the function of each part.
5. What are the advantages of a pressurized cooling system?
6. Why are diesel engine exhaust fumes less poisonous than gasoline engine exhaust fumes?
7. Explain the operation of the spark arrestor.
8. Explain what happens to the lubrication system when the oil filter becomes clogged.

9. Explain why most diesel engines use an oil cooler.

10. List the functions of the lubricating oil in a diesel engine.

11. Discuss the purpose and operation of the electrical system.

12. Why are batteries used on diesel engines connected in a series-parallel arrangement?

13. Why do large diesel engines use direct-air starting?

14. Explain the advantage of the hydro-starter over the air starter.

15. Discuss the operation of the basic carburetor.

16. What is the purpose of a transfer pump?

17. Explain how to time the injector on a Cummins diesel engine.

18. Explain how to adjust the injector on a Detroit diesel engine.

19. Discuss the differences among the various types of fuel injection systems.

20. Explain the timing procedures used on different injection systems.

UNIT 7

ENGINE DIAGNOSIS AND TUNEUP

OBJECTIVES

The student will be able:

- To make a visual inspection of the engine checking the cooling, lubrication, fuel, electrical, and air induction systems for leaks and/or damaged parts
- To make necessary adjustments and repairs to the cooling, lubricating, air induction, electrical, and fuel systems to bring the engine to its maximum performance
- To use a dynamometer to test engine performance

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
I. Engine Diagnosis	Explain why it is important to make a careful diagnosis of an engine prior to servicing or repairing it. Explain and show how to diagnose an engine including: • Listing of customer's complaints • Making a visual inspection of engine for external leaks and condition of coolant, lubricant, and fuel • Putting engine under load or using a dynamometer to check for engine temperature, oil pressure, fuel consumption, induction pressures, exhaust temperatures and pressure, electrical system performance, power output, and mechanical noises • Making a compression test • Checking operation of injector and pump • Determining work required to repair engine (tuneup or major overhaul)

CONTENT OUTLINE | UNDERSTANDINGS AND TEACHING APPROACHES

(Ref. C, p. 12-127; Ref. D, pp. 417-432; Ref. F, pp. 308-319; Ref. H, pp. 23-1—23-32; Ref. I, pp. 287-306)*

Have students diagnose their assigned engines, listing the conditions that need correcting and determining the amount of work involved to make the repairs. Check each student's diagnostic findings and explain any corrections necessary.

II. Engine Tuneup

Explain how periodic tuneups restore engines to their maximum performance and also prevent major damage.

Demonstrate how to tuneup an engine including the servicing of the following systems and major components:

A. Induction system

- Cleaning or changing air filters
- Changing oil in oil bath filters
- Changing ducting and hoses (when required)
- Tightening manifold
- Checking induction air preheater (if used)
- Checking crankcase ventilation system
- Checking blower for oil leaks and condition (if used)

(Ref. C, pp. 12-4—12-9)

B. Exhaust system

- Inspecting exhaust pipes, tubing, and mufflers
- Tightening manifold
- Checking turbocharger (if used)

(Ref. C, pp. 6-18—6-23; Ref. H, pp. 33-1—33-16)

C. Lubrication system

- Changing oil and oil filters
- Flushing oil system
- Correcting any external leaks

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*Reference citations are shown on page 109.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Adjusting oil pressure • Priming oil system • Lubricating all fittings (Ref. C, pp. 12-18—12-20; Ref. H, pp. 17-1—17-16, 23-12—23-14)
D. Cooling system	• Checking pressure cap and thermostat • Inspecting hoses and checking for leaks • Checking and/or lubricating water pump • Flushing cooling system • Checking and adding antifreeze • Checking coolant filters and conditioners • Adjusting fan belts (Ref. C, pp. 12-20—12-21; Ref. H, pp. 19-1—19-20, 23-14—23-16)
E. Fuel system	• Correcting fuel leaks • Checking fuel condition • Changing and cleaning fuel filter • Checking transfer pump pressures and/or volume • Checking injector and timing (if required) (Ref. I, p. 288) • Checking injection pump and timing (Ref. I, p. 291) • Bleeding fuel system • Checking governor and linkage • Adjusting carburetor on gasoline starting engines (Ref. C, pp. 12-15—12-18)

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

F. Engine

- Tightening cylinder head bolts
- Adjusting rocker arms
- Checking compression
- Checking tightness of all bolts

(Ref. C, pp. 12-10—12-12; Ref. H, pp. 23-29—23-31)

G. Electrical system

- Cleaning and tightening battery and cables
- Checking battery condition
- Testing generator or alternator output
- Adjusting belts
- Checking starter
- Adjusting or changing points on gasoline starting engines
- Checking timing of distributor or magneto on gasoline starting engines
- Changing spark plugs on gasoline starting engines

(Ref. C, pp. 12-12—12-15, 12-21—12-23; Ref. H, pp. 22-1—22-54, 23-24—23-29)

Explain why it is necessary to recheck engine operation after a tuneup has been performed.

Have students tuneup their assigned engines. Check the proficiency of each student's work.

Have students practice engine tuneup until they acquire the proficiency necessary for an entry mechanic.

Review Discussion

1. Explain how to diagnose malfunctions in a diesel engine.
2. Explain when a major engine overhaul would be necessary.

3. Discuss the engine condition information obtained by a compression test.
4. Why are engine tuneups necessary?
5. Why is servicing the air induction system an important part of an engine tuneup?
6. What is oil dilution and how is it caused?
7. Discuss the importance of coolant conditioners on diesel engines.
8. Explain how to diagnose the fuel system of a diesel engine.
9. Why is it important to recheck the engine performance after a tuneup has been performed?
10. What checks are made when testing an engine on a dynamometer?

UNIT 8

INJECTION SYSTEM AND CONTROLS

OBJECTIVES

The student will be able:

- To identify the different types of injection systems
- To test the operation of an injector
- To rebuild common types of injectors
- To disassemble and clean common injection pumps
- To inspect parts, order replacements, and reassemble common injection pumps
- To adjust and calibrate common injection pumps
- To rebuild common types of engine governors

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
I. Function and Types of Injectors	*Instruction in this area of diesel repair should be provided only if the proper specialized equipment is available. Individuals best suited for the instruction are those who exhibit a high degree of mechanical aptitude and are proficient in diesel engine repair.* Explain the function of the injection system including: • Metering the fuel injected • Timing the injection • Controlling the rate of injection • Atomizing the fuel • Distributing the fuel in the cylinder (Ref. C, pp. 5-1—5-2; Ref. D, pp. 206-208; Ref. F, p. 69; Ref. I, pp. 53-54)*

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*Reference citations are shown on page 109.

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	Explain the various types of injection systems (by metering principle) including: • Air • Common rail • Controlled bypass • Controlled suction • Variable suction • Port and helix • Variable stroke • Pressure and time (Ref. C, pp. 5-6—5-8; Ref. D, pp. 208-228; Ref. F, pp. 69-77; Ref. I, pp. 54-57)
II. Injectors and Nozzles	
A. Differential pressure operated injectors	Explain the design and operation of the following injector nozzles: • Pintle • Single and multi-hole • Pencil • Capsule (Ref. C, pp. 5-29—5-30; Ref. D, pp. 230-233; Ref. F, pp. 107-112; Ref I, pp. 57-59, 66-67, 75-76, 86-101, 104, 107-108, 111-116) Explain and show how to overhaul a differential pressure operated injector including: • Disassembling injector • Cleaning parts (Point out that under no circumstances should the lapped surfaces of the nozzle needle be touched.) • Inspecting parts

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Lapping sealing surfaces
- Checking and correcting needle lift
- Cleaning spray holes
- Grinding hole nozzle needles
- Lapping hole nozzle seats
- Making a needle drop test
- Bluing all external nozzle body parts
- Reassembling injector following manufacturer's specifications (Emphasize the importance of cleanliness during the rebuilding process, and explain why all parts are dipped in clean test fluid or diesel fuel prior to being reassembled.)
- Mounting injector on injector tester (Explain the safety precautions to take when testing an injector to prevent diesel fuel from penetrating the skin during discharge.)
- Testing injectors for opening pressure, leaks, atomization, shatter, and spray pattern
- Sealing injectors for storage or shipment

Have students practice servicing and testing injectors with different types of spray nozzles following test procedures given in the manufacturer's service manuals. Check each student's work for accuracy and correct procedures.

B. Unit injectors

Discuss the different types and operation of the unit injectors including:

- Low valve
- High valve
- Needle valve
- Variation in plungers and barrels

(Ref. D, pp. 233-239; Ref. F, pp. 92-95; Ref. I, pp. 93-97)

Explain and show how to service a General Motor's type unit injector including:

- Disassembling injector
- Cleaning and inspecting injector parts
- Lapping required parts
- Bluing parts (if required)
- Ordering parts required (those not included in normal overhaul kit)
- Reassembling injector
- Mounting injector in spray test fixture
- Testing injector for rack movement, holding pressure, leak down rate, spray angle, and pattern, and high pressure leaks
- Preparing injector comparator
- Testing injector flow rate
- Matching injectors with the same flow rate for each engine

Show variation in procedures for other types of unit injectors.

Have students practice servicing General Motor's type unit injectors following procedures listed in the manufacturer's service manuals. Check each student's work for accuracy and correct procedures.

C. Cummins PT injectors

Discuss the design and operation of the following Cummins injectors:

- PT flange and cylindrical
- PTB cylindrical
- PTC cylindrical

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

(Ref. D, pp. 237-239; Ref. F, pp. 98-101; Ref. I, pp. 85-87)

Explain and demonstrate how to service different types of Cummins injectors including:

- Disassembling injector
- Cleaning and inspecting injector parts
- Reassembling injector
- Testing and correcting spray angle and pattern, plunger to cup seating, plunger to barrel leakage, flow with adjustable orifice or burnished orifice
- Matching injector to a specific engine
- Preparing injector for shipment or storage

Have students practice servicing various types of Cummins injectors following procedures listed in the manufacturer's service manuals. Check each student's work for accuracy and correct procedures.

D. Miscellaneous injectors

Discuss the design and operation of other types of injectors including mechanical common rail spray valves. (Ref. D, pp. 219-221, 228-230)

Explain and demonstrate the maintenance procedures for other types of injectors including disassembling, cleaning, inspecting, reassembling, testing and adjusting.

Have students practice servicing other types of injectors.

III. Single and Multi-plunger Helix Controlled Pumps

A. Types

Discuss the design and operation of the following port and helix controlled injection pumps:

- Robert Bosch
- American Bosch

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Caterpillar
- Simms
- C.A.V.
- International Harvester
- Bendix

(Ref. C, pp. 5-17—5-21; Ref. D, pp. 212-213, 223-226; Ref. F, pp. 72-74, 78-84; Ref. I, pp. 54-59, 69-76, 89-93, 102-103, 106-109)

Use models and charts to illustrate such design variations in port and helix controlled pumps as:

- Port and helix
- Barrel and plunger mountings
- Delivery valves
- Control sleeve or arm
- Control rod
- Roller tappets (cam followers)
- Timing adjustment
- Camshafts and bearings
- Pressure relief valve
- Lubrication methods
- Fuel distribution on International Harvester's single and twin plunger pumps

(Ref. C, pp. 5-17—5-22; Ref. D, pp. 223-226; Ref. F, pp. 78-84; Ref. I, pp. 54-109)

B. Disassembly, cleaning, and inspection

Have students perform each operation of the complete servicing procedure immediately after it is demonstrated.

Explain and show how to disassemble, clean, and inspect port and helix controlled pumps including:

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

- Selecting special tools
- Cleaning pump externally
- Draining trapped fuel and lubricant
- Mounting pump on positioning vise
- Recording on worksheet information given on identification plate
- Removing hydraulic heads, if used
- Removing pump cover plate
- Removing governors and drive flanges
- Securing tappets so camshaft may be removed
- Removing camshafts
- Removing springs and plungers
- Removing delivery valve and holder
- Removing pump barrel

Explain why it is important to use special storage trays to keep parts in order.

Caution students not to touch lapped parts.

Demonstrate any special cleaning procedure such as the use of a glass peening machine.

Show how to inspect pump parts for usability including:

- Camshaft lobes
- Camshaft bearings and seal surfaces
- Bearings
- Tappets and rollers
- Plungers and barrels
- Springs and retainers

CONTENT OUTLINE | UNDERSTANDINGS AND TEACHING APPROACHES

- Control rack and sleeves
- Delivery valves
- Pump housing and miscellaneous parts

Show how to store lapped precision parts in clean diesel fuel or test fluid to prevent corrosion.

Have students practice disassembling, cleaning, and inspecting port and helix controlled pumps following procedures listed in the manufacturers' service manuals.

C. Reassembling

Demonstrate how to reassemble port and helix controlled pumps including:

- Dipping all parts in clean fuel oil
- Reinstalling barrels, delivery valve, and holder
- Reinstalling fuel rack and control sleeve
- Checking timing mark alinement
- Reinstalling spring, plunger, and retainer
- Reinstalling roller tappets
- Securing roller tappets for camshaft reinstallation
- Reinstalling camshaft and checking clearances
- Reinstalling plugs and covers
- Mounting hydraulic head, if used

Emphasize the importance of cleanliness during the reassembly of port and helix controlled pumps. Also, point out the importance of following the manufacturer's recommendations, particularly torque specifications.

D. Testing and calibrating

Explain and demonstrate how to test and calibrate a port and helix controlled pump including:

- Selecting test stand adapters, lines, and injectors
- Mounting pump on test stand (Emphasize the importance of wearing safety glasses when operating the test stand.)
- Calibrating pump by checking rack travel plunger phasing, shutoff, maximum delivery, and other check points in accordance with test specifications
- Reinstalling governor, if required, and recalibrating pump with governor
- Removing pump from test stand

Emphasize the importance of following the manufacturer's specifications.

Have students practice reassembling, testing, and calibrating port and helix controlled pumps. Check pump mounting before allowing students to operate test stand.

After students have become proficient on one name-brand pump, let them practice on another name-brand pump and continue this procedure until all students have had experience on the most common types of port and helix pumps. Check each student's work for accuracy and correct procedures.

E. Governors

Discuss the design and operation of the following governors used on port and helix controlled pumps:

- Mechanical - constant and variable speed
- Pneumatic
- Hydraulic

(Ref. C, pp. 5-22—5-25; Ref. D, pp. 265-315; Ref. F, pp. 273-286; Ref. I, pp. 229-240)

Use models and transparencies of governors to assist in the presentation of the topic.

Explain and show how to overhaul and repair different types of governors including:

CONTENT OUTLINE — UNDERSTANDINGS AND TEACHING APPROACHES

- Removing from pump or engine
- Disassembling
- Cleaning and inspecting parts
- Reassembling
- Reinstalling and adjusting

Have students practice repairing various types of governors following the procedures listed in the manufacturers' service manuals.

F. Automatic advance

Explain the operation of automatic advance mechanisms used on diesel engines. (Ref. F, pp. 75-77; Ref. I, pp. 64-66)

Explain and show how to repair automatic advance mechanisms including:

- Checking operation
- Disassembling and inspecting parts
- Reassembling and reinstalling

Have students practice repairing advance mechanisms.

IV. Distributor Pumps

A. Roosamaster and C.A.V.-DPA pumps

Explain the design and operation of Roosamaster and C.A.V.-DPA pumps including:

- Component parts and other functions
- Fuel flow
- End plate operation
- Metering valve action
- Charging and discharging operations
- Automatic advance operation
- Governor operation

(Ref. C, pp. 5-9—5-16; Ref. F, pp. 87-90; Ref. I, pp. 76-81, 99-102)

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	Point out the design variations between Roosamaster and C.A.V.-DPA pumps noting especially that the C.A.V.-DPA pump parts have been altered slightly and thus, cannot be interchanged with Roosamaster parts.
1. Disassembling	*Have students perform each operation of the complete servicing procedure immediately after it is demonstrated.* Explain and demonstrate how to overhaul and repair Roosamaster pumps starting with the DB pump including: • Mounting pump on disassembly fixture • Recording on a worksheet information given on name plate • Removing pump cover (hydraulic governor for some DPA pumps) • Removing shutoff cam and control levers and governor springs • Removing pivot shaft and governor arm • Inverting pump and removing advance covers and pistons • Loosening end plate screws and fittings • Removing cam and head locating bolts • Removing hydraulic head (*Caution students not to drop governor parts.*) • Placing hydraulic head on fixture and removing end plate, transfer pump, and rotor snap ring • Removing delivery valve • Inverting head in fixture and removing governor weight retainer and pump cam (*Caution students not to let rotor fall out of the head.*) • Removing leafspring or springs from rotor

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Removing cam rollers, shoes, and plungers • Removing rotor from head (*Caution students not to touch the rotor and head lapped surfaces.*)
2. Cleaning and inspecting	Explain and show how to clean and inspect a distributor pump following the procedures and specifications listed in the manufacturer's service manual. Explain why finely machined and lapped parts are stored in clean test oil or diesel fuel.
3. Reassemblying	Explain and demonstrate how to reassemble a pump following the procedures and specifications listed in the manufacturer's service manual including: • Installing new seals and gaskets • Dipping finely fitted parts in test oil during reassembly • Placing oil on all seals during reinstallation • Following torque specifications set by manufacturer • Setting roller to roller dimensions • Checking roller concentricity • Installing parts relative to pump's rotation • Checking and marking pump timing (if new cam or weight retainer drive flange is installed) • Setting governor linkage • Adjusting electric shutoff • Using new fuel shutoff cams and/or locking clips • Installing pump drive shaft (noting timing marks)

CONTENT OUTLINE

UNDERSTANDINGS AND TEACHING APPROACHES

Repeat the above disassembly, inspection, and reassembly procedures following the manufacturer's manual for Roosamaster DC, C, or CB pumps and C.A.V.-DPA pumps with hydraulic and mechanical governors.

4. Calibrating

Explain and demonstrate how to calibrate and test a pump following manufacturer's manual including:

- Selecting appropriate test stand adapters, injectors, test oil and lines
- Mounting pump securely on test stand
- Determining pump rotation
- Starting and operating stand at low speed with pump throttle at maximum speed (until transfer pump and pump housing is primed)
- Checking for leaks at rated speed (Indicate that the transfer pump should not exceed 130 p.s.i.)
- Checking transfer pump suction (no less than 15" of mercury on DB and 18" of mercury on DC pumps)
- Noting return oil flow (between 100 to 450 cc. per minute at 35 p.s.i. for Roosamaster pumps)
- Making checks of fuel delivery (at specified points in test specifications—maximum allowed difference between cylinders is 5 percent)
- Checking full load fuel delivery
- Setting torque screw (if used)
- Checking mechanical or electric shutoff
- Setting idle r.p.m. and automatic advance
- Removing pump from stand
- Wiring throttle lever in full load position until pump is installed on engine

- Capping fuel inlets and outlets with cap plugs

Have students practice servicing, testing, and calibrating Roosamaster and C.A.V.-DPA pumps following manufacturer's specifications.

Be sure that students are wearing safety glasses when operating the test stand. Check each pump before student operates test stand. Check each student's work for accuracy and correct procedures.

B. American Bosch distributor pumps

Discuss and explain the design and operation of the various types of the American Bosch distributor pumps including:

- Metering principle
- Component parts and their function
- Fuel flow and distribution
- Lubrication
- Timing devices
- Governor—types, function, and operation

(Ref. D, pp. 226-229; Ref. F, pp. 84-87; Ref. I, pp. 62-70)

1. Disassemblying

Have students perform each operation of the complete servicing procedure immediately after it is demonstrated.

Explain and show how to disassemble an American Bosch distributor pump including:

- Cleaning pump externally
- Removing external timing device, if used, and mounting pump on work positioning vise
- Selecting special tools required
- Recording on a worksheet information given on name plate

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Removing pump covers and control unit • Loosening delivery valve • Removing hydraulic head • Removing tappet and roller • Removing governor and supply pump • Removing camshaft (including Intravance, if used) • Disassembling, cleaning, and inspecting all parts Point out and demonstrate variations in the procedure for other models of pumps.
2. Cleaning and inspecting	Demonstrate how to clean and make a detailed parts inspection for an American Bosch distributor pump following manufacturer's service manual. Obtain replacements for all worn parts. *Check service manual for any required modifications.*
3. Reassembling	Explain and show how to reassemble an American Bosch distributor pump following the manufacturer's service manual including: • Dipping all parts in clean test oil • Coating all lapped surfaces with clean test oil • Using proper torque on all fasteners • Checking all clearances as specified • Lubricating seals and O rings with oil • Checking each moving part for binding • Making all governor adjustments
4. Calibrating	Explain and demonstrate how to calibrate and test an American Bosch distributor pump including: • Selecting test stand adapters

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Calibrating pump following manufacturer's specifications *Have students practice servicing, testing, and calibrating American Bosch distributor pumps. Check each student's work for accuracy and following manufacturer's suggested procedures.*
C. Robert Bosch distributor pump	Discuss and explain the design and operation of a Robert Bosch distributor pump including: • Principle of metering • Fuel flow and distribution • Lubrication • Automatic timing device • Principle of governor operation Emphasize the importance of following the manufacturer's specifications.
1. Disassembling	*Have students perform each operation of the complete servicing procedure immediately after it is demonstrated.* Explain and show how to disassemble a Robert Bosch distributor pump including: • Cleaning pump externally • Mounting pump on work positioner • Removing control levers and valves • Loosening delivery valves and vent screw • Removing hydraulic head, plunger, automatic timing device, face cam, cam ring, supply pump, and drive shaft • Disassembling parts
2. Cleaning and inspecting	Demonstrate how to clean and make a detailed inspection of the individual parts of a Robert Bosch distributor pump including the condition of the:

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	• Plunger and bore • Control sleeves and their bores • Cam and cam ring • Valves • Supply pump
3. Reassemblying and calibrating	Explain and show how to reassemble and calibrate a Robert Bosch distributor pump including: • Lubricating parts with clean test oil • Noting timing marks • Checking for proper clearance • Lubricating O ring seals with oil prior to reassembly • Using recommended torque for all fasteners • Using proper test stand adapters and injectors • Calibrating pumps following manufacturer's specifications • Preparing pump for storage or shipment *Have students practice servicing, testing, and calibrating Robert Bosch distributor pumps. Check each student's work for accuracy and following manufacturer's suggested procedures.*
D. Cummins PT fuel pumps	Discuss the design and operation of a Cummins PT fuel pump including: • Identification of pumps • Parts and their function • Fuel flow • Fuel pressure regulation • Auxiliary equipment

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	(Ref. D, pp. 237-239; Ref. F, pp. 97-101; Ref. I, pp. 82-87)
1. Disassembling and cleaning	*Have students perform each operation of the complete servicing procedure immediately after it is demonstrated.* Explain and show how to disassemble and clean a Cummins fuel pump including: • Cleaning pump externally • Mounting pump on work positioner • Removing pulsation damper, drive cover, and governor • Removing shut down plunger valve, gear pump, and spring pack cover and parts • Removing throttle assembly • Removing fuel filter and tachometer drive
2. Inspection, repair, and reassembly	Demonstrate how to inspect, repair, and reassemble a Cummins PT fuel pump including the following parts or assemblies: • Pump housing components • Gear pumps • Governor components • Shutdown valves • Tachometer drive • Pulsator diaphram • Torque converter (if used) • Pressure regulator • Throttle assembly
3. Calibrating	Demonstrate how to calibrate a Cummins PT fuel pump including: • Mounting pump on test stand

CONTENT OUTLINE	UNDERSTANDINGS AND TEACHING APPROACHES
	- Connecting flow panel - Testing and/or adjusting - Gear pump suction - Pump vacuum - Total fuel flow - Governor cutoff speed - Throttle leakage - Idle fuel pressure - Manifold fuel pressure - Check point pressure - Weight assist pressure - Air leakage
	Emphasize the importance of following manufacturer's repair procedures and specifications when working on injection equipment.
	Check each student's work for accuracy and correct procedures. Have students practice servicing, testing, and calibrating Cummins PT fuel pumps.

Review Discussion

1. Explain the various metering principles used on today's fuel injection pumps.
2. List the most common injection systems in use.
3. List the injection pumps using the port and helix metering principle.
4. Explain the operation of differential pressure operated injection nozzles.
5. Discuss the operation and timing procedure for Cummins injectors.
6. List how to test GM unit injectors.

Injection System and Controls

7. Discuss the design variations of the common port and helix multi-plunger pumps.

8. Explain the operation of the International Harvester's single and dual plunger distributor pumps.

9. Discuss the differences between the Roosamaster and the C.A.V.-DPA pumps.

10. Explain why cleanliness is so important when working on fuel injection equipment.

11. Why is the high pressure discharge of injectors or fuel lines considered dangerous?

12. What happens when finely fitter or lapped surfaces are touched?

13. Discuss the operation of the various types of governors in common use.

14. What is meant by "speed droop"?

15. How does an American Bosch distributor pump meter the amount of fuel injected?

16. Explain the operation of a delivery valve.

17. How does an Robert Bosch distributor pump meter the amount of fuel injected?

18. Discuss the operation of the automatic timing device of a Robert Bosch distributor pump.

19. Where is the calibration data for an injection pump found?

20. Discuss the purpose of the Cummins fuel pump.

SAMPLE FINAL EXAMINATION

Sample Final Examination Part I — Fill-In Statements

Directions: For each statement, write the word or phrase that, when inserted in the blank, will complete the statement correctly.

1. The three requirements necessary to make any internal combustion engine run are ignition, fuel and air mixture, and COMPRESSION.
2. The one requirement in the above question that is automatic on the diesel engine and does not require special equipment is IGNITION.
3. The cam follower type valve lifter is different from the other lifters because it has a (an) ROLLER CONTACTING THE CAM.
4. Piston pin bushings are lubricated by OIL SPLASH OR OIL PRESSURE.
5. Certain metals are alloyed with steel to give it SPECIAL PROPERTIES.
6. The tightness of a connecting rod bearing is checked by the BEARING CRUSH.
7. The types of piston used in diesel engines are the crosshead and the TRUNK.
8. Internal combustion engines are cooled by water or AIR.
9. Low compression on a diesel engine may be caused by faulty valves, heat gasket, or RINGS.
10. The removable part of a cylinder is called the SLEEVE.
11. When the crankshaft on a four-stroke cycle engine has turned 500 times, the camshaft has turned 250 times.
12. When compared to the size of the intake valve, the exhaust valve is usually SMALLER.
13. The valve contact area should be located at the CENTER OF THE VALVE FACE.
14. Valve guide wear can be checked by using a new valve and a (an) DIAL INDICATOR.
15. If the compression increases when taking a wet compression test, it usually indicates faulty RINGS.

16. The normal width of a valve seat should be about ONE-SIXTEENTH OF AN INCH.

17. A copper gasket may be softened for reuse by HEATING AND FAST COOLING.

18. The shape of the skirt on a cam-ground piston is OVAL.

19. The inside of a piston head on a heavy duty diesel engine is cooled by the use of OIL.

20. A turbocharger is driven by the engine EXHAUST GASES.

21. The bottom of a wet sleeve is sealed by the use of O RINGS.

22. On a four-stroke cycle engine, valve overlap occurs between the exhaust stroke and the INTAKE STROKE.

23. One turn of the micrometer thimble moves the spindle .025 OF AN INCH.

24. The Roosamaster injection pump meters the fuel by VARIABLE SUCTION.

25. The Cummins injection pump meters the fuel by PRESSURE AND TIME.

26. When installing bushings, it is important to line up the OIL HOLES.

27. The Roosamaster distributor pump is lubricated by DIESEL FUEL.

28. When the oil filter clogs on a full-flow system, the bearings still receive oil because of the BYPASS.

29. Cylinder head bolts should be removed in a sequence that is the REVERSE OF TIGHTENING.

30. The delivery valve of an injection pump prevents fuel from returning into the PUMP CHAMBER.

31. In a turbocharger, the device driven by the turbine is called the COMPRESSOR WHEEL.

32. The greatest enemy of the injection system is DIRT.

33. Air in the injection system must be removed by BLEEDING THE SYSTEM.

34. The GM unit injector is operated by the engine CAMSHAFT.

35. Injection pump plungers and barrels must be replaced as a unit because of their PRECISION FIT.

Sample Final Examination Part II — Multiple Choice

Directions: For each statement, place the letter of the choice that completes the statement most accurately in the space provided to the left of the number.

__B__ 1. A dial indicator is used to measure

A. crankshaft diameters
B. valve to guide clearance
C. bearing crush
D. piston pin diameter

__D__ 2. Gears are made hard on the surface by

A. heating and dropping in water
B. oxidation
C. heating and slow cooling
D. case hardening in carbon

__B__ 3. The purpose of the camshaft is to

A. operate the crankshaft when starting the engine
B. open and close valves at the proper time
C. move the pistons up and down in sequence
D. operate the generator

__C__ 4. The purpose of the flywheel is to

A. balance the engine
B. act as an engine governor
C. store kenetic energy
D. drive the crankshaft

__D__ 5. On a diesel engine, the fuel is ignited by

A. an electric spark
B. a make and brake system
C. a glow plug
D. the heat of compressed air

__A__ 6. Which of the pumps listed below is not used as an oil pump?

A. centrifical pump
B. rotor pump
C. vane pump
D. gear pump

__C__ 7. The filtering materials used in an oil filter are

A. steel wool and steel shavings
B. coke and charcoal
C. porous paper and cotton
D. sawdust and wood chips

C 8. To obtain a compression pressure of 400 p.s.i., a diesel engine would have to be cranked at

A. 50 r.p.m.
B. 100 r.p.m.
C. 200 r.p.m.
D. 300 r.p.m.

B 9. Lubricating oil is a mixture of

A. water and grease
B. hydrocarbons
C. hydrogen and oxygen
D. gasoline and diesel oil

D 10. The oil pressure on a diesel engine is regulated by the

A. oil pump
B. injection pump
C. oil galley
D. pressure relief valve

C 11. Which of the characteristics listed below is not associated with lubricating oil

A. gravity
B. flash point
C. grain size
D. viscosity

B 12. On lubricating oil that is classified as SAE 30 DM, the DM stands for

A. diesel severe high sulphur fuel
B. diesel severe low sulphur fuel
C. diesel medium high sulphur
D. diesel medium low sulphur

A 13. The pump used in the cooling system of an automotive diesel engine is a

A. centrifical pump
B. gear pump
C. vane pump
D. slipper pump

D 14. Piston rings are commonly made of

A. aluminum
B. copper
C. nickel
D. cast iron

D 15. The functions of oil passages in the crown of a piston is to

A. wash away carbon deposits
B. provide lubrication
C. aerate the oil supply
D. lower the temperature of the piston

B 16. The temperature range in the exhaust manifold near the exhaust valve is

A. 500 to 700°F.
B. 700 to 850°F.
C. 850 to 1000°F.
D. 1000 to 1250°F.

C 17. Pressure caps are used on radiators to

A. lower the boiling point
B. prevent loosing antifreeze
C. raise the boiling point
D. tighten fan belts

D 18. One of the functions of an injection system is to

A. filter the fuel
B. mix the fuel
C. weigh the fuel
D. meter the fuel

C 19. If the injection of diesel fuel is too early, it will cause

A. hard starting
B. black exhaust smoke
C. high pressure and knocking noises
D. blue exhaust smoke

A 20. If the injection of diesel fuel is late, it will cause

A. loss of power and black smoke
B. high pressure and a knocking noise
C. engine to run cold
D. loss of power and blue exhaust smoke

C 21. The number of valves used in a controlled bypass injection pump are

A. 1
B. 2
C. 3
D. 4

D 22. On the port and helix controlled injection pump, the amount of fuel and the end of the injection is controlled by

A. changing the stroke of the plunger
B. the variable suction orifice
C. changing the closing of the suction valve
D. rotation the plunger with the helix

C 23. On the variable stroke injection pump,changes in the amount of fuel injected is accomplished by

A. rotating the plunger
B. controlling the bypass valve
C. changing the stroke of the plunger
D. using a helix on a plunger

D 24. The best place to locate an oil cooler is

A. in the crank case
B. before the oil filter
C. between the oil filters
D. after the oil filter

D 25. Liquid diesel fuel will burn instantly at about

A. 300°F
B. 500°F
C. 800°F
D. 1000°F

A 26. The plungers of a Rossamaster pump are activated by

A. an internal cam ring through rollers and shoes
B. spring pressure
C. hydraulic pressure
D. air pressure

D 27. The type of fuel supply pump used with the American Bosch injection pumps is a

A. pneumatic type
B. centrifugal type
C. diaphragm type
D. plunger type

A 28. The number of vanes in a C.A.V. transfer pump are

A. two
B. four
C. five
D. seven

C 29. The American Bosch pneumatic governor obtains the required vacuum from

A. a separate vacuum pump
B. a plunger type pump
C. the venturi assembly in the intake manifold
D. one side of the fuel pump

D 30. The volume of fuel from the C.A.V. distributor type injection pump is controlled by

A. the pressure of the fuel
B. length of the stroke of the plunger
C. length of time the fuel may enter the inlet port
D. both the pressure of the fuel and time the inlet port is open

A 31. The type of mechanical fuel injection used by General Motors Corporation is a

A. unit injector system
B. common rail system
C. distributor system
D. pump controlled system

D 32. The multiple hole type nozzle provides good

A. injection
B. pressure
C. penetration
D. atomization

B 33. The advantage of using welded tubing in an exhaust system is its

A. ease of installation
B. low resistance to the flow of exhaust gases
C. low cost
D. durability

D 34. The American Bosch injection pump type APE is a

A. throttle bypass type
B. diaphragm type
C. throttle inlet type
D. port controlled type

D 35. The speed of a turbocharger on a diesel engine

A. decreases as the speed of the engine increases
B. increases as the speed of the engine increases
C. decreases as the engine load increases
D. increases as the engine load increases

Sample Final Exam Part III — Matching

Directions: In the space provided to the left of each item in Column I, write the letter of the word or phrase from Column II which best matches the Item in Column I.

Column I

D 1. Hard starting
L 2. Distributor injection pump
H 3. Automotive diesel engine
J 4. Flywheel
A 5. Plunger and barrel
K 6. Bearing clearance
C 7. Port and Helix
E 8. Sleeves or liners
N 9. Governor
F 10. Black smoke from exhaust

Column II

A. Parts changed in pairs
B. Precision bearing insert
C. Fuel metering principle
D. Late timing
E. Cylinder parts
F. Restricted air cleaner
G. Valve timing
H. High speed diesel engine
I. Burning oil
J. Kinetic energy
K. Plastic gauge
L. Hydraulic head
M. PT fuel system
N. Flyweight

Sample Final Exam Part IV — Problems

1. *Directions:* In the space provided, indicate with an "A" those parts from the display that could be used in the reassembly process and with a "U" those parts that should be discarded.

(U) 1. Crankshaft Journals (.002" OUT OF ROUND)
(A) 2. Cylinder Liner (TAPERED .0005")
(U) 3. Cylinder Liner "O" rings (USED)
(U) 4. SAE Grade 8 Bolts (USED)
(A) 5. Compression Rings (RING GAP WITHIN LIMITS)

(A) 6. Connecting Rod (BIG END BORE WITHIN SPECIFICATION)

(U) 7. Piston (SKIRT BADLY SCARED)

(A) 8. Oil pump gears (PROPER CLEARANCE)

2. *Directions:* From the list given below, number in the correct order, in the space provided, the steps a mechanic would follow when he performs a valve job. Cross out any unnecessary steps.

(No) Drain coolant

(11) Check spring tension and squareness

(7) Reface seats

(12) Install valves

(4) Pressure check cylinder head

(No) Change injector

(10) Lap valves

(8) Reface valves

(No) Adjust rocker arms

(9) Check valve head protrusion

(5) Check valve guide clearance

(3) Clean cylinder head and valves

(No) Bleed fuel lines

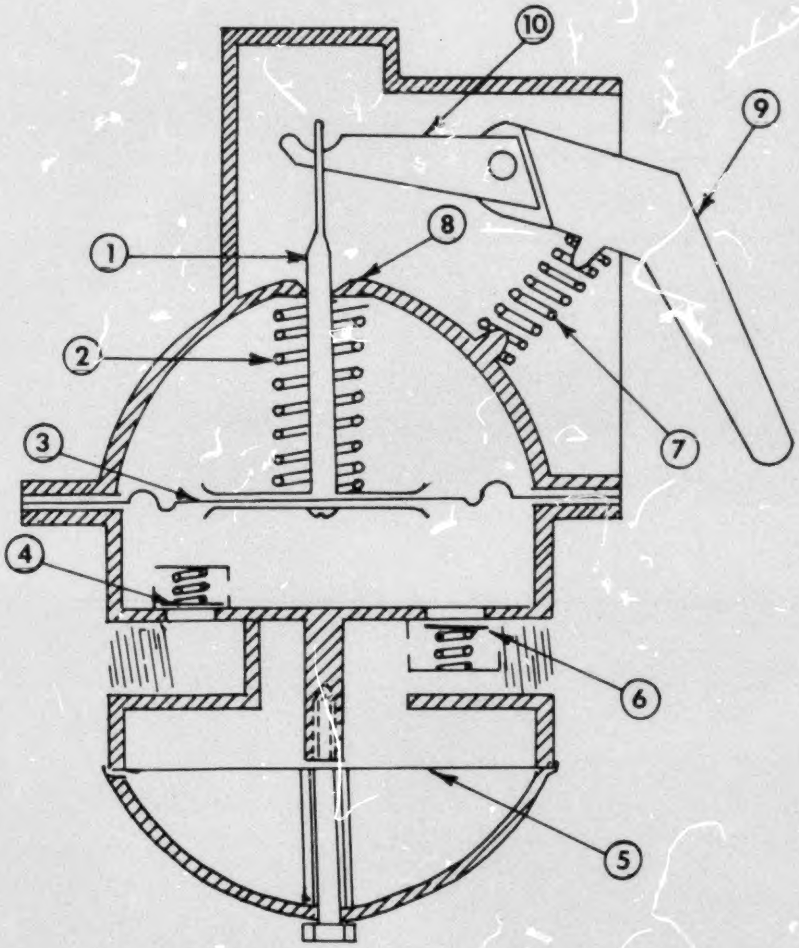
(1) Inspect head for cracks

(6) Check for warped head

(2) Remove springs, retainer and valves

Sample Final Exam Part V — Identification

Directions: In the space provided after each number, write the correct name of the part indicated by the matching number on the illustration given below.



1. DIAPHRAGM PULL ROD
2. DIAPHRAGM RETURN SPRING
3. PUMP DIAPHRAGM
4. INLET VALVE
5. PULSATOR DIAPHRAGM
6. OUTLET VALVE
7. ROCKER ARM SPRING
8. OIL SEAL
9. ROCKER ARM
10. FUEL PUMP LINK

USING AUDIOVISUAL MATERIALS

Audiovisual materials are both a tool for teaching and an avenue for learning. Commercially made films, filmstrips, film loops, and slides may be used to supplement the regular instruction. Titles of some of these items are listed in the bibliography.

Photographic technology has advanced to a level where it is possible, with relative ease, to produce your own slides, movies, or filmstrips. Even sound and automation are easily added. Also, many schools have adequate audiovisual facilities and skilled personnel so that an instructor is able now to create and produce his own audiovisual aids.

The first step might be the development of a set of 2 by 2 inch slides to assist in presenting a complex procedure. Slides are inexpensive; simple to make; and can be organized, rearranged, and updated very easily. Also, slides are equally well suited for individual use or group presentation.

Slides may be used by individual students for review of material already presented or by students who missed the original presentation. When used on an individual basis, the slides permit the student to progress at his own pace. Such individual use requires the development of a printed script and directions to guide the student through the materials and to emphasize the important concepts related to the topic.

File cards may be used to plan the slides and accompanying script. Place each fact or idea in the lower one-third of a file card. Include a summary of the purpose of the slide or statement that will be said when the slide is projected. Use the upper portion of the card to make a visual representation of the slide itself. Let the slide carry the message, and add only enough script to clarify what is being shown. Review the cards and make necessary revisions. Keep the content of each slide simple and limited to one point or concept. Titles and captions should be a part of every presentation. Limit the title slides to less than 15 words. Use dry-transfer or three-dimensional letters that are at least three-eighths of an inch high in order to be legible when projected.

Good slides can be produced with an inexpensive, automatic, single lens reflex camera and color film. Additional light for shop setups can be obtained by using electronic flash, flash bulbs, or photoflood lamps. Easily attached close-up lenses might be helpful when photographing small parts or showing fine details. Bracket the exposure to be sure of getting a usable slide and thus eliminate the work of making the setup over again. A tripod will be necessary to hold and position the camera for many of the pictures. Obtain additional assistance for your project from the local Director of Educational Communications.

PREPARING AND USING TRANSPARENCIES

The overhead projector is a flexible classroom teaching device. It gives the instructor maximum freedom to adapt the material being used to the needs and interests of the group by letting him control the pace, emphasis, and sequence of the presentation. Because the projector is positioned in front of the class, the instructor is able to maintain a more effective rapport with the students, observe their reactions, and lead group discussions more effectively.

Colorful transparencies with multiple overlays break complicated events into comprehensible units and easily show the interrelationships among the different parts. Transparencies may be prepared easily by hand. The following suggestions are presented to help instructors plan and produce their own original transparencies.

- Organize the content of the transparency carefully and plan for horizontal projection.
- Keep the content of the transparency simple.
- Use letters and symbols that are at least one-fourth of an inch high. Use a lettering guide or dry-transfer letters and symbols to produce attractive titles or labels.
- Use color to make the transparency attractive, but only enough color for emphasis. Color-toned sheets or colored ink may be used to identify parts of a drawing or picture.
- Leave a three-fourths of an inch margin on all sides of a transparency.
- Use multiple overlays (one transparency over another) for the development of a concept or to show steps. Attach overlays to the sides of the mount with tape or special transparency hinges.
- Keep master and overlays in register with crosshair marks in opposite corners.
- Use a sliding or hinged mask to control the rate of disclosure when more than one step is included on a transparency.
- Place the completed transparency in a special mount. Fasten the film to the mount with pressure-sensitive tape.

GLOSSARY

Additive: A substance added to fuels, lubricants, and coolants to improve their original characteristics.

Advance: A change in the timing of the injection or ignition so it occurs earlier during the compression stroke.

Aftercooler: A device to cool air which, prior to its induction into a cylinder, has been heated by being compressed in a turbocharger.

Air cleaner: A device that filters foreign particles from the air entering the engine cylinders.

Air-fuel mixture: The combination of air and fuel that is delivered to the engine cylinders.

Air starter: A device used to start diesel engines with compressed air.

Alinement: The process of bringing the various parts of a unit into proper positions relative to each other or to a predetermined location.

Atmosphere pressure: The pressure developed at sea level by the weight of air pressing downward on an object (14.7 p.s.i.)

Atomization: A method of breaking a liquid into very fine particles.

Backlash: The amount of play in a mechanical system.

Back pressure: The resistance to the free flow of liquids or gases through a system.

Balance shaft: A shaft used to eliminate harmonic vibration in engines.

Barrel: A part of the injection pump in which the plunger travels.

Bearing crush: The difference between the outside diameter of a bearing and the bore for the bearing. Actually each half of the bearing is a little more than a half circle and when the bearing caps are tightened, the bearing shells are forced tightly into the bearing bore.

Block: The part of the engine that contains the cylinders.

Blower: An engine driven device consisting of two counter rotating paddle wheels that is used to increase the air charge of the engine, usually a Roots type blower.

Bore: The interior diameter of an engine cylinder.

Boring: A method of renewing the cylinder wall by cutting it out to a specified size.

Brake horsepower: The actual power produced by an engine that may be found by the use of a prony brake or a dynamometer.

Break-in period: The time that an engine is operated between the installation of new or rebuilt parts and the time when the parts are considered worn to the correct fit.

Bypass filter: An oil filter that constantly filters a portion of the oil flowing through the engine.

Bypass valve: A valve that can open and allow a fluid to pass through in a passageway other than its normal channel.

Calibrate: A method of adjusting the graduations of a measuring instrument.

Cam follower: The portion of the push rod that is in conact with the cam.

Centrigrade: A measurement of temperature at which the boiling point of water is 100 degrees and the freezing point is 0 degrees.

Ceramic filter: A filtering device that uses porous ceramic material as the filtering agent.

Cetane number: A measure that indicates the ignition quality of a diesel fuel.

Closed crankcase ventilating system: A system in which the crankcase vapors are drawn into the intake system to prevent the escape of unburned hydrocarbons into the air.

Combustion: The rapid burning of the air-fuel mixture in the cylinder.

Combustion chamber: The space in the cylinder when the piston is at top dead center.

Compression gauge: A device which measures the amount of pressure developed in the cylinder during cranking.

Compression ratio: The ratio between the maximum volume in the cylinder with the piston at bottom dead center and the minimum volume with the piston at top dead center.

Compression stroke: The movement of the piston from bottom dead center to top dead center when both valves are closed.

Counterbalance: A weight attached to a moving part in order to reduce vibration.

Cycle: A series of events that recur regularly such as the piston strokes of intake, compression, power, and exhaust.

Cylinder head: The removable section of the engine that covers the upper end of the cylinder bores.

Cylinder sleeve: A liner used as a replaceable surface for a cylinder.

Delivery: Injecting the fuel into the cylinder in a metered amount.

Delivery valve: The outlet valve on the injection pump.

Detergent: A substance added to fuel, oil, or a coolant which aids to keep the parts clean.

Diagnosis: The process of determining the cause of a malfunction.

Diaphragm: A flexible membrane that separates two parts of a closed container.

Diesel engine: An internal combustion engine that uses the heat of compressed air to ignite the fuel.

Displacement: The total volume of air expelled by the piston when it travels from bottom dead center to top dead center.

Distribution tubes (cooling system): Tubes used in the engine cooling area to guide and direct the flow of the coolant to vital areas.

Double Flare: A flare in the end of tubing which utilizes two wall thicknesses.

Dry sleeve: A cylinder sleeve application in which the coolant does not touch the sleeve itself.

Dynamometer: A machine used to measure the horsepower output of an engine.

Emission control device: A device or system designed to reduce contaminants expelled into the air from an engine.

Emissions tester: A device for sampling exhaust gases to measure the amount of air contaminants present.

Exhaust gas analyzer: An instrument used to check the exhaust gases to determine combustion efficiency of the engine.

Exhaust stroke: The movement of the piston from bottom dead center to top dead center when the exhaust valve is open.

Fillet: A rounding joint between two parts which are connected at an angle.

Flash point: The temperature at which a given oil will ignite and flash into flame.

Four-stroke cycle: The operations of intake, compression, power, and exhaust which make up complete sequence for one type of internal combustion engine.

Fuel injector: A device that atomizes and forces fuel into the cylinder or intake manifold.

Fuel jet: A calibrated opening that meters a specific quantity of fuel.

Fuel pump: A device that delivers fuel to the injector.

Fuel rack: A device that controls the individual injection pump plungers and the amount of fuel delivered.

Full-flow oil filter: An oil filter that filters all of the oil passing through the engine.

Gasket: A material placed between two parts to insure proper sealing.

Glaze: A very smooth, glassy deposit that accumulates on cylinder walls.

Glaze breaker: An abrasive tool used to remove the glaze from cylinder walls.

Governor: A device designed to automatically control the speed of an engine.

Horsepower: A unit for measuring the rate at which work is done.

Impeller: The rotating part of a blower that is used to move a liquid or a gas.

Inhibitor: A substance added to oil, fuel, or coolant to prevent an unwanted action such as foaming or rusting.

Injection: The process of forcing fuel into the combustion chamber by the use of high pressure.

Injector: The pump that meters a specific amount of fuel directly into the cylinder.

Inlet port: The opening in the cylinder of a two-stroke cycle engine through which air enters the cylinder.

Intake stroke: The movement of the piston from top dead center to bottom dead center when the intake valve or port is open.

Intake valve: The valve through which the fuel mixture or air is admitted to the cylinder.

Jet: A small hole or orifice used to control the flow of fuel or air.

Journal: That part of a shaft that is prepared to accept a bearing.

Land: The metal between two grooves.

Lap or lapping: A process of fitting two surfaces together by coating them with an abrasive and rubbing them together.

Liter: A metric unit of volume.

Magnaflux: A special chemical-magnetic process that is used to check parts for cracks.

Meter: A metric unit of length.

Millimeter: A metric unit of length.

Nozzle: An opening or jet through which fuel passes when it is discharged into the combustion chamber or air stream.

Oil galley: A pipe or drilled passageway in the engine that is used to carry oil from one area to another.

Oil slinger: A disk on the crankshaft which prevents oil from being pushed out of the engine.

Oil spray nozzle: A device used to cool the inside of the piston on diesel engines.

Orifice: a small opening or hole.

Overhead valves: An engine design with the valves located in the head.

Piston boss: The area of the piston that supports the piston pin.

Piston displacement: The amount of air expelled by the piston when it is moved through the full length of its stroke.

Piston pin or wrist pin: A steel pin that is used to fasten the piston to the connecting rod.

Piston ring: A split ring installed in a groove in the piston.

Piston skirt: The portion of the piston below the rings that is designed to take the side thrust of the piston.

Pony engine: A small gasoline engine that is used to start large diesel engines.

Port: An opening in the head or cylinder through which air or exhaust gas pass.

Positive chrankcase ventilating system: A system that delivers the crankcase vapors, normally expelled into the air, to the intake manifold for reburning.

Power: The rate at which work is accomplished.

Power stroke: The movement of the piston from top dead center to bottom dead center when the air-fuel mixture is burned, the gases expand, and both valves are closed.

Preloading: The process of adjusting antifriction bearings so they are under a mild pressure.

Press fit: A condition of fit between two parts that requires pressure to force the parts together.

Pressure relief valve: A valve designed to open at a specific pressure.

Prony brake: A machine used to measure the brake horsepower of an engine.

Push rod: A rod that transmits the movement of the cam to the rocker arm.

Relief valve: A valve that will open when the pressure goes above a predetermined level.

Rocker arm: An arm used to transmit the upward motion of the push rod to a downward or opening motion of the valve stem.

Scavenging: The process of removing exhaust gases from a cylinder.

Shroud: A metal enclosure around a fan or engine which guides and facilitates the flow of air.

Snap ring: A split ring that is snapped into a groove in a shaft to hold bearings, thrust washer, and gears in place.

Sodium-cooled valve: A valve in which the stem is partially filled with metallic sodium to speed the transfer of heat from the valve head to the engine block.

Stroke: The distance the piston moves from top dead center to bottom dead center.

Supercharger: An engine driven impeller wheel that compresses air inducted into an engine to increase power output.

Thermostat: A temperature sensitive device used to control another device.

Troubleshooting: The process of diagnosing a problem by observation and tests.

Tuneup: The process of bringing the operation of an engine back to its original specifications.

Turbocharger: A device which utilizes exhaust pressure to drive a supercharger.

Turbulence: The rapid swirling action imparted to the air or air-fuel mixture in a manifold or cylinder.

Two-stroke cycle: An engine that produces a power stroke for each revolution of the crankshaft.

Vacuum: A pressure that is less than normal atmospheric pressure.

Vacuum gauge: A device that measures decreased atmospheric pressure.

Valve: A device used to open or close an opening.

Valve lifter (tappet): A device that rides on the cam lobe and transfers the cam motion to the pushrod or valve stem.

Valve overlap: The duration, expressed in degrees, when both the intake and exhaust valves are partially open.

Valve seat: The matched surface upon which the face of the valve rests when it is closed. The two common angles for this seat are forty-five and thirty degrees.

Vane: A thin plate that is attached to a driven unit which throws off air or liquid or receives the thrust imparted by moving air or liquid striking the vane.

Vibration damper: A round weighted device attached to the front of the crankshaft to minimize the torsional vibration.

Water jacket: The area around the cylinders and valves which is left hollow so that water may be circulated for cooling.

Wet sleeve: A cylinder sleeve application in which the coolant contacts a major portion of the sleeve itself.

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_____ *Fuel injection nozzles & nozzle holders.* Broadview, Ill. The Corporation. n.d.

_____ *Generators and regulators for motor vehicles.* Broadview, Ill. The Corporation. n.d.

_____ *Generators and regulators for motor vehicles.* Broadview, Ill. The Corporation. n.d.

_____ *Pressure pumps.* Broadview, Ill. The Corporation. n.d.

_____ *Starting motors.* Broadview, Ill. The Corporation. n.d.

_____ *Variable range speed governors.* Broadview, Ill. The Corporation. n.d.

Stanadyne/Hartford Division. *Charts and pictures of pumps.* Hartford, Conn. The Corporation. n.d.

Standard Motor Products, Inc. Hygrade Products Division. *Carburetor trouble shooter pocket guide.* Long Island City, N.Y. The Division. n.d.

_____ *Ignition & carburetion tune-up specifications.* Long Island City, N.Y. The Division. 1971.

L. S. Starrett Co. *How to read, use, and care for micrometers and vernier gages.* Athol, Mass. The Company. n.d.

U. S. Department of Labor, Occupational, Safety, and Health Adm. *Safety in your future.* Washington, D.C. U. S. Government Printing Office. 1966.

Worthy, J. C. *What employees want.* Chicago, Ill. Science Research Associates, Inc. 1956.

FILMS

The ABC of hand tools. General Motors Corp. 1946. 33 min. sound. color. Loan - General Motors Corp.

The ABC of the automobile engine. General Motors Corp. 1972. 18 min. sound. color. Loan - General Motors Corp.

The ABC of the diesel engine. General Motors Corp. 1973. 18 min. sound. color. Loan - General Motors Corp.

Checking injection timing. Cummins Engine Co., Inc. 10 min. sound. color. Purchase - Cummins Engine Co., Inc.

Combustion in action. General Motors Corp. 1966. 19 min. sound. color. Loan - General Motors Corp.

Engines. Cummins Engine Co., Inc. 22 min. sound. color. Purchase - Cummins Engine Co., Inc.

Fundamentals of electricity. Sterling Educational Films. 1967. 13 min. sound. color. Purchase - Sterling Educational Films.

Magnetism. Sterling Educational Films. 1967. 13 min. sound. color. Purchase - Sterling Educational Films.

Magnetism and electricity. McGraw-Hill Films. 1965. 17 min. sound. color. Rent - Syracuse University Film Library.

No time to waste. General Motors Corp. 1971. 14 min. sound. color. Loan - General Motors Corp.

Servicing dry type air cleaners. International Harvester Co. 20 min. 16 mm. sound. color. Purchase - International Harvester Co., Farm and Industry Division.

The smallest fraction. Cummins Engine Co., Inc. 13 min. sound. color. Purchase - Cummins Engine Co., Inc.

The spark of power. Champion Spark Plug Co. 1965. 14 min. sound. color. Free - Modern Talking Picture Service and Buchan Pictures.

There's more to cooling. Cummins Engine Co., Inc. 23 min. sound. color. Purchase - Cummins Engine Co., Inc.

To clear the air. American Petroleum Institute. 1967. 20 min. sound. color. Loan - New York State Petroleum Council.

Turbocharger. Cummins Engine Co., Inc. 15 min. sound. color. Purchase - Cummins Engine Co., Inc.

Watt's a VOM. Cummins Engine Co., Inc. 10 min. sound. color. Purchase - Cummins Engine Co., Inc.

FILMSTRIPS AND SLIDES

APE injection pumps. American Bosch Arma Corp. 35 mm slides. Purchase - American Bosch Arma Corp.

Basic engine service. International Harvester Co. sound. color. Purchase - International Harvester Co., Construction Equipment Division.

Diagnose it first. Dana Corporation. 80 frames. script supplied. color. Loan - Dana Corporation.

Dial indicator method of injection adjustment. Cummins Engine Co., Inc. Purchase - Cummins Engine Co., Inc.

Diesel engine fuel system. International Harvester Co. Purchase - International Harvester Co., Construction Equipment Division.

Diesel fuel systems, I-V. Caterpillar Tractor Co. 35 mm slides. Avg. 35 slides per part. scripts supplied. color. Purchase - Caterpillar Tractor Co.

Diesel starting systems, I-II. Caterpillar Tractor Co. 35 mm slides. Avg. 30 slides per part. script supplied. color. Purchase - Caterpillar Tractor Co.

Electrical systems. John Deere Co. 295 slides. color. Purchase - John Deere Co.

Engine theory and operations, 1 and 2. Cummins Engine Co., Inc. Purchase - Cummins Engine Co., Inc.

Engine tuneup, in-line engine with variable speed governor. General Motors Corp. 29 frames. script supplied. Purchase - General Motors Corp., Technical Center.

Engines. John Deere Co. 300 slides. color. Purchase - John Deere Co.

Fuel filtering systems. J. I. Case Co. 31 slides. sound. color. Purchase - J. I. Case Co.

Fuels, lubricants, and coolants. John Deere Co. 60 slides. color. Purchase - John Deere Co.

Governors. Cummins Engine Co., Inc. Purchase - Cummins Engine Co., Inc.

Governors for diesel injection equipment. 35 mm slides. script supplied. color. Purchase - American Bosch Arma Corp.

Heads, valves, and camshafts. Caterpillar Tractor Co. 30 slides. script supplied. color. Purchase - Caterpillar Tractor Co.

Installing and timing Bosch fuel injection pumps. J. I. Case Co. 35 mm slides. sound. color. Purchase - J. I. Case Co.

Installing piston rings in farm tractors. Dana Corporation. script supplied. color. Loan - Dana Corp.

Introduction to the automotive electrical system. Delco-Remy. 15 min. sound. color. Purchase - Commercial Service Co.

Measuring tools. Caterpillar Tractor Co. 41 slides. script supplied. color. Purchase - Caterpillar Tractor Co.

188 cu. in. diesel engine. J. I. Case Co. 67 slides. sound. color. Purchase - J. I. Case Co.

Operation and adjustment of the PT fuel pump. Cummins Engine Co., Inc. Purchase - Cummins Engine Co., Inc.

Orientation to the diesel engine. International Harvester Co. sound. Purchase - International Harvester Co., Construction Equipment Division.

Pistons, rings, and liners. Caterpillar Tractor Co. 57 slides. script supplied. color. Purchase - Caterpillar Tractor Co.

Power trains. John Deere Co. 195 slides. color. Purchase - John Deere Co.

Preventive maintenance for truck engines. General Motors Corp. 114 frames. sound. Purchase - General Motors Corp., Technical Center.

Principles of the PT mechanical governor. Cummins Engine Co., Inc. Purchase - Cummins Engine Co., Inc.

PSB injection pump. American Bosch Arma Corp. 35 mm slides. script supplied. color. Purchase - American Bosch Arma Corp.

PT injectors. Cummins Engine Co., Inc. Purchase - Cummins Engine Co., Inc.

Rebuilding the cylinder head assembly. General Motors Corp. 90 frames. sound. Purchase - General Motors Corp., Technical Center.

Safety at work. Jam Handy. 10 filmstrips. Avg. length 56 frames. sound. color. Purchase - Scott Educational Division.

Shop tools. John Deere Co. 45 slides. color. Purchase - John Deere Co.

Theory of the PTG fuel system. Cummins Engine Co., Inc. Purchase - Cummins Engine Co., Inc.

Troubleshooting. Cummins Engine Co., Inc. Purchase - Cummins Engine Co., Inc.

Vernier scales. Caterpillar Tractor Co. 11 slides. script supplied. color. Purchase - Caterpillar Tractor Co.

Wrong way Charlie tackles blower rebuilding. General Motors Corp. 61 frames. sound. Purchase - General Motors Corp., Technical Center.

Wrong way Charlie tackles troubleshooting. General Motors Corp. 95 frames. sound. Purchase - General Motors Corp., Technical Center.

Your job and safety. Caterpillar Tractor Co. 19 slides. script supplied. color. Purchase - Caterpillar Tractor Co.

FILM LOOPS

The complete circuit. Sterling Educational Films. 2 min. sound. color. Purchase - Sterling Educational Films.

Dynamometer setup and procedures. DCA Educational Products., Inc. sound. color. Purchase - DCA Educational Products, Inc.

Dynamometer test procedures; cylinder balance. DCA Educational Products, Inc. sound. color. Purchase - DCA Educational Products, Inc.

Dynamometer test procedures; power and carburetion. DCA Educational Products, Inc. sound. color. Purchase - DCA Educational Products, Inc.

Electricity and magnetism. Universal Education and Visual Arts. 2 min. sound. color. Purchase - Universal Education and Visual Arts.

The four-cycle engine. Thiokal Chemical Corp. 6 min. sound. color. Purchase - Carousel Films, Inc.

How to time the two-cycle engine. Thiokal Chemical Corp. 6 min. sound. color. Purchase - Carousel Films, Inc.

Properties of magnets. Universal Education and Visual Arts. 2 min. sound. color. Purchase - Universal Education and Visual Arts.

Testing a fuel pump. Modern Learning Aids. 4 min. color. Purchase - Modern Learning Aids.

Timing an engine. Modern Learning Aids. 4 min. sound. color. Purchase - Modern Learning Aids.

The two-cycle engine. Thiokal Chemical Corp. 6 min. color. sound. Purchase - Carousel Films, Inc.

TRANSPARENCIES AND TRANSPARENCY MASTERS

Cooling system. DCA Educational Products, Inc. nine transparencies. Purchase - DCA Educational Products, Inc.

Electrical system. DCA Educational Products, Inc. 13 transparencies. color. Purchase - DCA Educational Products, Inc.

Dial indicators. DCA Educational Products, Inc. 11 transparencies. color. Purchase - DCA Educational Products, Inc.

Electrical system. John Deere Co. 190 transparency masters. Purchase - John Deere Co.

Engines. John Deere Co. 200 transparency masters. Purchase - John Deere Co.

Exhaust system. DCA Educational Products, Inc. one transparency. color. Purchase - DCA Educational Products, Inc.

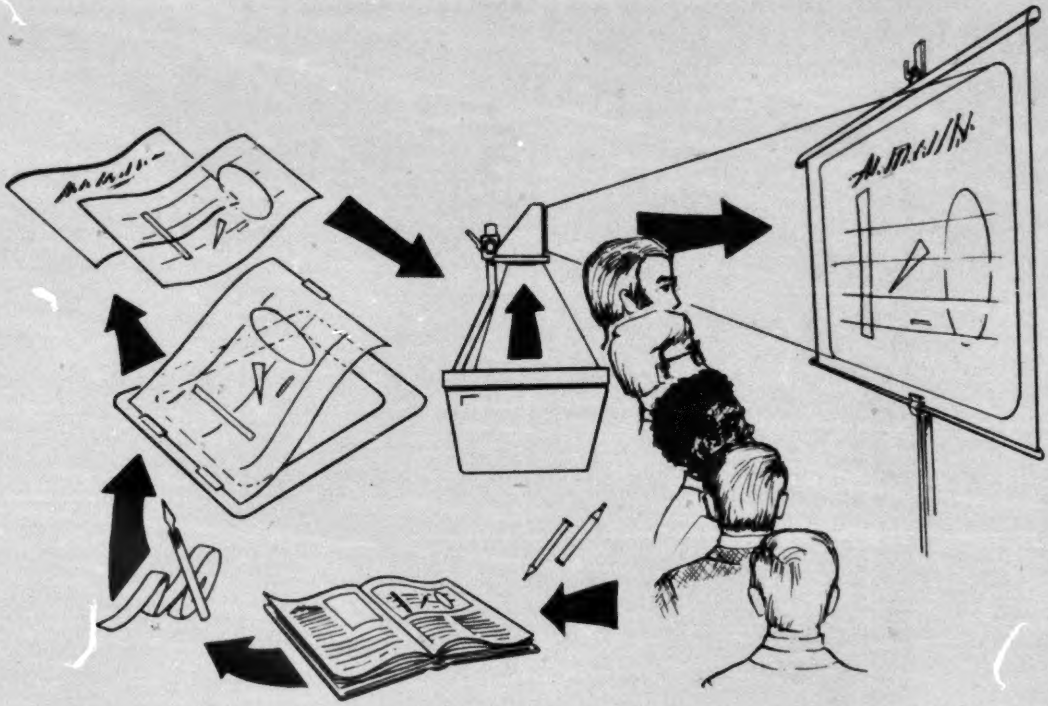
Fuel & lubricants. American Association for Agricultural Engineering and Vocational Agriculture. 58 transparency masters. Purchase - The Association.

Fuel system. DCA Educational Products, Inc. six transparencies. color. Purchase - DCA Educational Products, Inc.

Micrometers and vernier gages. DCA Educational Products, Inc. 16 transparencies. color. Purchase - DCA Educational Products, Inc.

Power trains. John Deere Co. 130 transparency masters. Purchase - John Deere Co.

Safety in the shops. 3 M Co. 23 visuals. color. Purchase - 3 M Co.



APPENDIX

APPENDIX 1

USE COMPRESSED AIR WITH CAUTION

Compressed air is dangerous. Use it properly to prevent injury to yourself and your fellow workmen. Safety goggles should always be worn when using compressed air.

At 40 pounds per square inch, compressed air directed against the skin can cause an injury that resembles a burn. This is in addition to any dirt, fragments, or chips that may be forced into the flesh.

Such an air jet, if directed into the mouth, can rupture the lungs and intestines. It has been estimated that as little as four pounds of pressure can rupture the bowels. Aimed at the eyes it can cause blindness. Aimed at the ear it can rupture the ear drum and might cause brain damage.

Compressed air should never be used to blow dust and dirt out of the hair or clothing. The danger of ruining your ears or eyes is obvious. A further danger can come from air being driven into the flesh through a scratch or cut which could cause a swelling and agonizing pain and even bubbles of air to get into the bloodstream.

Compressed air should never be turned onto a fellow worker. When this has happened it not only has maimed people but it also has killed some individuals.

Use compressed air as carefully as you would handle a loaded gun - both are deadly.

APPENDIX 2

THE UNIVERSITY OF THE STATE OF NEW YORK
THE STATE EDUCATION DEPARTMENT
ALBANY, NEW YORK 12224

ASSOCIATE COMMISSIONER FOR
INSTRUCTIONAL SERVICES

February 1973

EYE SAFETY DEVICES
Education Law and Regulations
of the Commissioner of Education

To: City, Village and District Superintendents of Schools
Diocesan Superintendents
Supervising Principals
Principals of Public, Private and Parochial Elementary and Secondary Schools
Presidents of Public and Private Institutions of Higher Learning

Section 141.8 Part 141 of the Regulations of the Commissioner of Education amended by the Board of Regents, February 1971, provides for conformity to revised standards for eye safety devices.

The Z87 standard (which superseded an earlier Z2 standard) prescribes quality and strength specifications for safety eyewear to be used by laboratory and shop students, their teachers and visitors. It is recommended that all bid and purchase terminology include the phrase: "Equipment must meet or exceed all ANSI Z87 standard requirements" and that suppliers be required to furnish written proof to this effect.

Personal "safety eyeglasses" - unless validated in writing as complying with all Z87 lens and frame specifications by the ophthalmic specialist who fabricated them - should not be allowed in educational labs and shops, or in industry. Likewise, contact lenses do not provide approved eye protection. The selection, maintenance, and disinfection of approved safety eyewear is detailed on page 29 of the Z87 document.

You are urged to revise, adopt and implement local policies to fit your particular circumstances at the earliest possible time.

Any inquiry concerning these regulations should be directed to the appropriate unit in the Department.

William L. Bitner
WILLIAM L. BITNER

EDUCATION LAW

§ 409-a. Eye safety devices for certain students and teachers.

1. The board of education, trustees, principal or other person in charge of every public or private school or educational institution within the state, wherein shops or laboratories are conducted providing instructional or experimental programs involving:

   a. Hot solids, liquids or molten metals; or

   b. Milling, sawing, turning, shaping, cutting, or stamping of any solid materials; or

   c. Heat treatment, tempering, or kiln firing of any metal or other materials; or

   d. Gas or electric arc welding; or

   e. Repair or servicing of any vehicle; or

   f. Caustic or explosive chemicals or materials,

shall arrange for and require, in accordance with regulations of the commissioner, that every student and teacher participating in any such program wear eye safety devices at the times and under the conditions prescribed in such regulations.

2. The commissioner shall by regulation prescribe the safety standards to be met before the use of any eye safety device may be required and shall include in such regulations requirements relating to the times and conditions when and under which such eye safety devices shall be worn.

3. Visitors to such shops or laboratories shall be furnished with and required to wear such eye safety devices at the times and under the conditions prescribed in such regulations while in such shops or laboratories.

REGULATIONS OF THE COMMISSIONER OF EDUCATION

§ 141.8 Eye Safety devices

(a) It shall be the duty of the board of education, trustees or person in charge of every public and private school and educational institution in this State to provide eye safety devices for the protection of employees, pupils and visitors and to require that such devices be worn in shops or laboratories whenever such persons are in dangerous proximity to a potential eye hazard. In shop or laboratory situations where the activity is such that hazards may develop without warning, safety devices must be worn by all persons in the area.

(b) A potential eye hazard is deemed to be present in any situation where there is a possibility of an eye injury or impairment of sight and shall include, but not be limited to, activities in a shop or laboratory involving:

(1) hot solids, liquids or molten metals; or

(2) milling, sawing, turning, shaping, cutting or stamping of any solid materials; or

(3) heat treatment, tempering, or kiln firing of any metal or other materials; or

(4) gas or electric arc welding; or

(5) repair or servicing of any vehicle; or

(6) caustic or explosive chemicals or materials.

(c) Eye safety devices within the meaning of this regulation shall include face shields, goggles, safety glasses, welding helmets, hoods and other specialized equipment in compliance with the American National Standard Practice for Occupational and Educational Eye and Face Protection, Z87.1-1968, promulgated by the American National Standards Institute, Inc.

(d) It shall be the duty of the board of education, trustees or person in charge of every public and private school and educational institution to insure that said devices are properly repaired, cleaned and stored. Procedures should be adopted to prevent the spread of germs or diseases when the user changes.

Development of District Policies for Eye Protection
Suggested Guidelines

The amended Regulations of the Commissioner of the State of New York effective March 1, 1971 outline in general terms the time and place when eye protective devices should be worn. Boards of education are urged to adopt rules for implementing the Law and Regulations of the Commissioner of Education. Industrial quality eye protective devices as used in the Regulation are defined as those devices meeting standards of the American National Standard Practice For Occupational and Educational Eye and Face Protection, Z87.1-1968, promulgated by the American National Standards Institute, Inc.

Therefore, the following are provided as guides to implementation of eye safety programs. It is suggested:

- That school districts formulate specific policies for the implementation of eye protection programs.
- That school district committees for developing district policy relating to eye safety devices include:
  - professional staff members representing instructional areas
  - community resource persons familiar with industrial eye safety programs
  - school district insurance representative(s)
  - optometrist or other medical authority
  - school district legal authority
- That policies be reviewed periodically to implement amendments to the legislation and the Regulations of the Commissioner.
- That suppliers be required to meet or exceed the standards of the American Standard Practices For Occupational and Educational Eye and Face Protection, Z87.1-1968, promulgated by the American National Standards Institute, Inc.
- That sanitary storage facilities relating to eye protective devices be planned for each shop, laboratory or instructional area where eye protective devices are required.
- That quality eye safety devices be available for the protection of all students in classes where potential hazards exist.

Acquisition and Maintenance

We receive numerous inquiries about the Z87 standard. Therefore, we enclosed a reprint of important excerpts from the Z87.1-1968 USA Standard Practices for Occupational and Educational Eye and Face Protection.

The total publication was screened and the selection chart, information on maintenance and disinfection, fitting of goggles and spectacles, and selection of shade numbers for welding filters were considered to be the most pertinent.

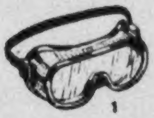
The following two notes relate to general acquisition policies:

- Z87 specifications for eye safety devices are no different than those set forth in the old Z2 specifications. The revision came about as a result of separating respiratory devices from the previous eye and face specifications.
- State agencies and political subdivisions may secure eye safety devices from state contract, thereby assuring compliance with regulations.

These excerpts from the Z87.1-1968 USA Standard Practices for Occupational and Educational Eye and Face Protection relate to the use of eye safety devices. This information represents factors for school districts to consider in the acquisition and maintenance of eye protective devices. The remainder of the Bulletin is information about technical testing and production standards.

Selection Chart

Recommended Eye and Face Protectors for Use in Industry, Schools, and Colleges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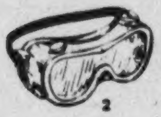
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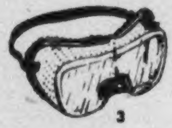
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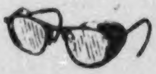
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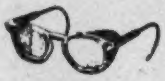
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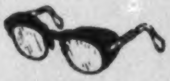
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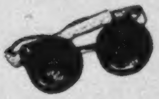
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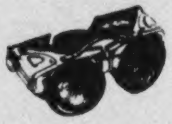
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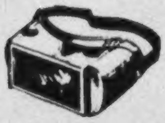
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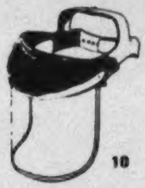
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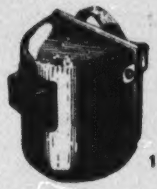
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1. **GOGGLES**, Flexible Fitting, Regular Ventilation
2. **GOGGLES**, Flexible Fitting, Hooded Ventilation
3. **GOGGLES**, Cushioned Fitting, Rigid Body

*4. **SPECTACLES**, Metal Frame, with Sideshields

*5. **SPECTACLES**, Plastic Frame, with Sideshields

*6. **SPECTACLES**, Metal-Plastic Frame, with Sideshields

** 7. **WELDING GOGGLES**, Eyecup Type, Tinted Lenses (Illustrated)

7A. **CHIPPING GOGGLES**, Eyecup Type, Clear Safety Lenses (Not Illustrated)

** 8. **WELDING GOGGLES**, Coverspec Type Tinted Lenses (Illustrated)

8A. **CHIPPING GOGGLES**, Coverspec Type, Clear Safety Lenses (Not Illustrated)

** 9. **WELDING GOGGLES**, Coverspec Type, Tinted Plate Lens

10. **FACE SHIELD** (Available with Plastic or Mesh Window)

11. **WELDING HELMETS

*Non-sideshield spectacles are available for limited hazard use requiring only frontal protection.

**See appendix chart "Selection of Shade Numbers for Welding Filters."

APPLICATIONS

OPERATION	HAZARDS	RECOMMENDED PROTECTORS: Bold Type Numbers Signify Preferred Protection
ACETYLENE–BURNING ACETYLENE–CUTTING ACETYLENE–WELDING	SPARKS, HARMFUL RAYS, MOLTEN METAL, FLYING PARTICLES	7, 8, 9
CHEMICAL HANDLING	SPLASH, ACID BURNS, FUMES	2, 10 (For severe exposure add 10 over 2)
CHIPPING	FLYING PARTICLES	1, 3, 4, 5, 6, 7A, 8A
ELECTRIC (ARC) WELDING	SPARKS, INTENSE RAYS, MOLTEN METAL	9, 11 (11 in combination with 4, 5, 6, in tinted lenses, advisable)
FURNACE OPERATIONS	GLARE, HEAT, MOLTEN METAL	7, 8, 9 (For severe exposure add 10)
GRINDING–LIGHT	FLYING PARTICLES	1, 3, 4 5, 6, 10
GRINDING–HEAVY	FLYING PARTICLES	1, 3, 7A, 8A (For severe exposure add 10)
LABORATORY	CHEMICAL SPLASH, GLASS BREAKAGE	2 (10 when in combination with 4, 5, 6)
MACHINING	FLYING PARTICLES	1, 3, 4, 5, 6, 10
MOLTEN METALS	HEAT, GLARE, SPARKS, SPLASH	7, 8 (10 in combination with 4, 5, 6, in tinted lenses)
SPOT WELDING	FLYING PARTICLES, SPARKS	1, 3, 4, 5, 6, 10

Selection of Shade Numbers for Welding Filters[5]

The following is a guide for the selection of the proper shade numbers of filter lenses or plates used in welding. Shades more dense than those shown for various operations may be selected to suit the individual's needs.

Welding Operation	Suggested Shade Number
Shielded metal-arc welding 1/16-, 3/32-, 1/8-, 5/32-inch diameter electrodes	10
Gas-shielded arc welding (nonferrous) 1/16-, 3/32-, 1/8-, 5/32-inch diameter electrodes	11
Gas-shielded arc welding (ferrous) 1/16-, 3/32-, 1/8-, 5/32-inch diameter electrodes	12
Shielded metal-arc welding 3/16-, 7/32-, 1/4-inch diameter electrodes	12
5/16-, 3/8-inch diameter electrodes	14
Atomic hydrogen welding	10-14
Carbon-arc welding	14
Soldering	2
Torch brazing	3 or 4
Light cutting, up to 1 inch	3 or 4
Medium cutting, 1 inch to 6 inches	4 or 5
Heavy cutting, over 6 inches	5 or 6
Gas welding (light), up to 1/8 inch	4 or 5
Gas welding (medium), 1/8 inch to 1/2 inch	5 or 6
Gas welding (heavy), over 1/2 inch	6 or 8

Fitting of Goggles and Spectacles

A3.1 Cup Goggles. The first step in fitting cup goggles is to adjust the nose bridge. Both the ball and link-chain and leather or plastic strap bridges of goggles are adjustable to accommodate the individual wearer. Both types of bridges usually have some means for shortening or lengthening. In either case, to shorten or lengthen the bridge, the instructions of the manufacturer should be followed. Chain, leather, or plastic not needed after adjustment should be cut off. The chain should be insulated to protect the nose of the wearer.

The proper procedure for adjusting headbands is to keep the band loose enough to slip two fingers under it, palm side down, without stretching. Headbands should be worn low and flat and approximately at the base of the skull in order to hold goggles in a comfortable position. Most cup goggles are thinner and slanted away at the lower nasal sides, which makes for comfort as well as easy identification in getting them right side up.

A3.2 Spectacles. The first step in fitting spectacles is to determine the proper eye and bridge sizes. This is done best by using fitting samples and placing the sample spectacles on the nose to arrive at the proper size. The adjustable rocker pads should fit flush against the sides of the nose without allowing the metal bridge of the spectacles to rest on the nose bridge of the wearer. The small metal arms, to which the pearloid pads are attached, can be readily adjusted by round nose pliers which are especially designed for this purpose. To fit the temples comfortably over the ears, hold the spectacle firmly in one hand and shape the bow of the temple gradually by drawing it slowly between thumb and forefinger of other hand. Temples should be angled down from frame to ear so that the lenses will be perpendicular to the line of vision.

Prescription safety spectacles should be fitted only by qualified optical personnel.

6.4 Maintenance and Disinfection of Eye Protectors

6.4.1 *Maintenance*

6.4.1.1 It is essential that the lenses of eye protectors be kept clean. Continuous vision through dirty lenses can cause eye fatigue and become a contributory factor to accidents. Daily cleaning of eye protectors is recommended.

6.4.1.2 *Pitted or scratched lenses reduce vision and seriously reduce protection. They shall be replaced immediately.*

6.4.1.3 Replace headbands. Slack, worn-out, sweat-soaked, knotted, or twisted headbands do not hold the eye protector in proper position. Visual inspection can determine when the elasticity is reduced to a point beyond proper function.

6.4.1.4 To prolong the life of eye protectors, they shall be placed in suitable cases or containers between periods of use.

6.4.2 ***Issue and Use.*** Protectors are a personal item and should be for the individual and exclusive use of the person to whom they are issued. If circumstances require reissue, *the protectors shall be thoroughly cleaned and disinfected as hereinafter described.*

6.4.3 *Disinfection*

6.4.3.1 *General.* When a person is assigned protective equipment, it is recommended that this equipment be cleaned and disinfected regularly, without sharing by another person unless disinfected as herein specified.

6.4.3.2 *Procedure.* Thoroughly clean all surfaces with soap or suitable detergent, and warm water. Carefully rinse all traces of soap or detergent. Completely immerse the protector for 10 minutes in a solution of modified phenol, hypochlorite, or quaternary ammonium compounds, in a strength specified by the manufacturer, at a room temperature of 68°F. Remove protector from solution and suspend in a clean place for air drying at room temperature, or with heated air. Do not rinse because this will remove the residual effect.

Ultraviolet disinfecting equipment may be utilized in conjunction with the washing procedure above, when such equipment can be demonstrated to provide comparable disinfection.

Protectors showing need for extensive cleansing should be disassembled to the extent possible without tools, prior to the washing and disinfection procedure. Replace defective parts with new ones.

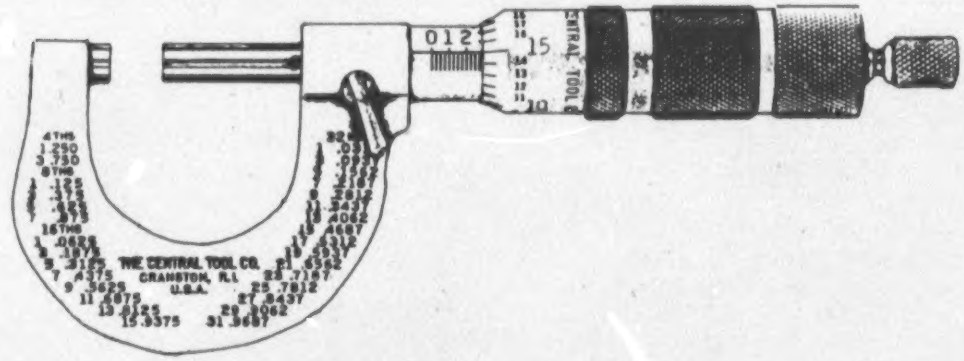
6.4.3.3 *Storage.* The dry parts or items should be placed in clean, dust-proof containers to protect them.

APPENDIX 3

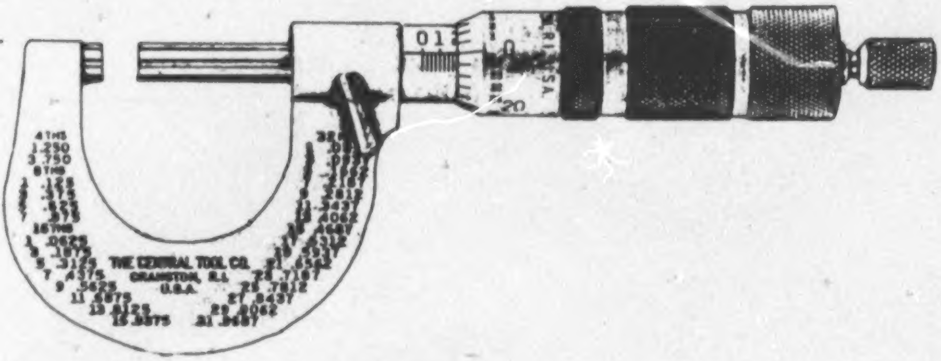
READING PRECISION MEASURING TOOLS

Directions: In the space provided to the left of each instrument, place the dimension indicated on the measuring tool.

1. ______


0 1 2
15
10
CENTRAL TOOL
4THS
1.250
3.750
8THS
16THS
THE CENTRAL TOOL CO.
CRANSTON, R.I.
U.S.A.

2. ______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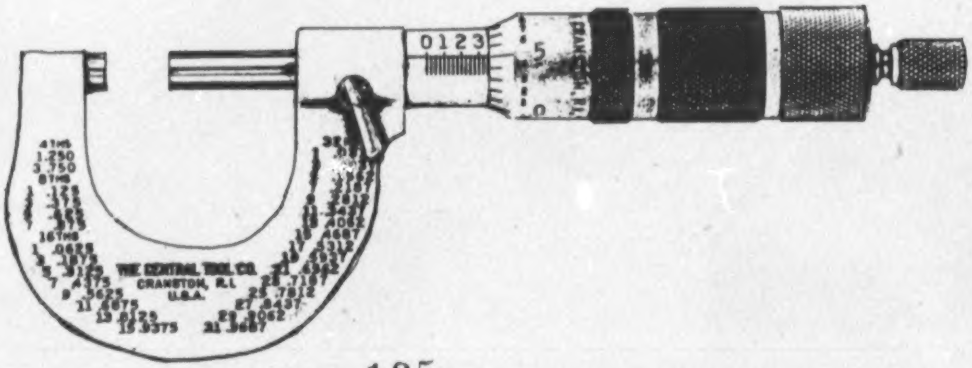
0
20
4THS
1.250
3.750
8THS
16THS
THE CENTRAL TOOL CO.
CRANSTON, R.I.
U.S.A.

3. ______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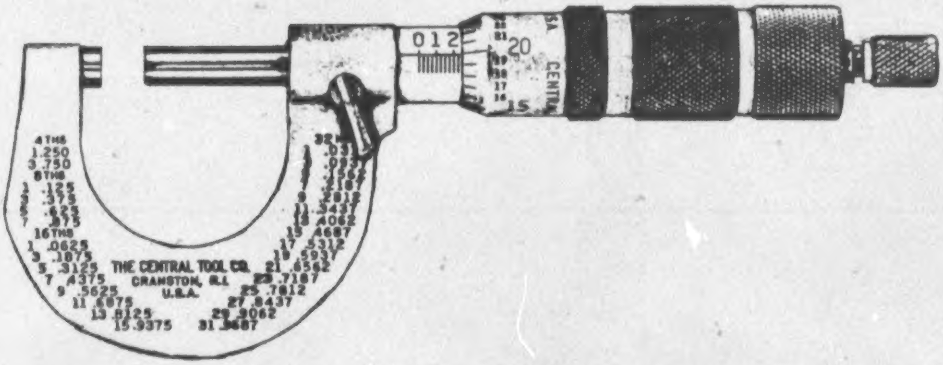
5
0
CRANSTON, R.I.
4THS
1.250
3.750
8THS
16THS
THE CENTRAL TOOL CO.
CRANSTON, R.I.
U.S.A.

4. ________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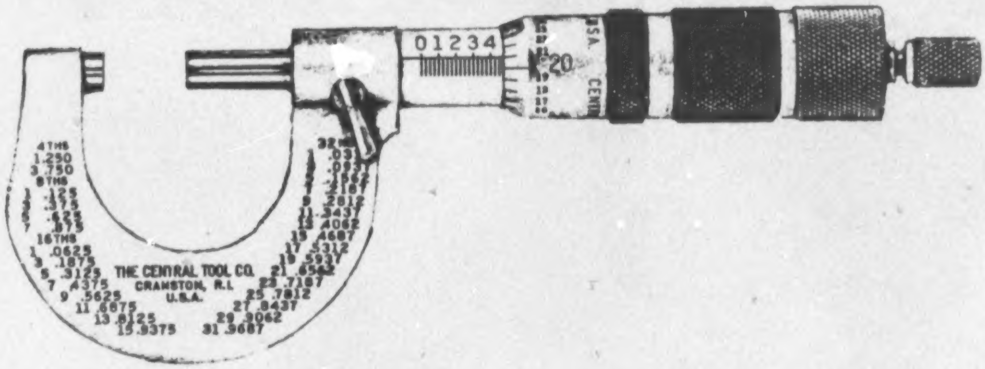
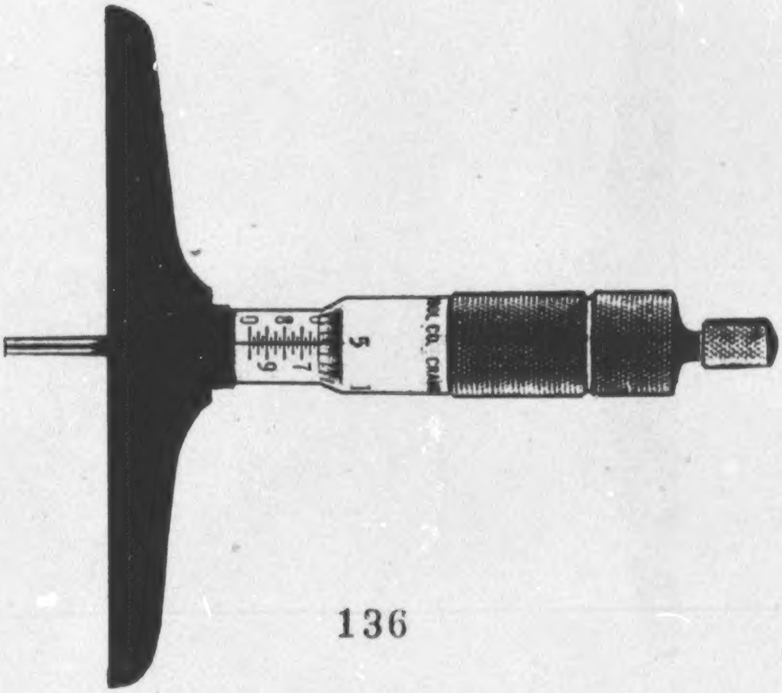
20
15
CENTRAL
4THS
1 .250
3 .750
8THS
1 .125
3 .375
5 .625
7 .875
16THS
1 .0625
3 .1875
5 .3125
7 .4375
9 .5625
11 .6875
13 .8125
15 .9375
32NDS
.0312
.0937
.1562
.2187
9 .2812
11 .3437
13 .4062
15 .4687
17 .5312
19 .5937
21 .6562
23 .7187
25 .7812
27 .8437
29 .9062
31 .9687
THE CENTRAL TOOL CO.
CRANSTON, R.I.
U.S.A.

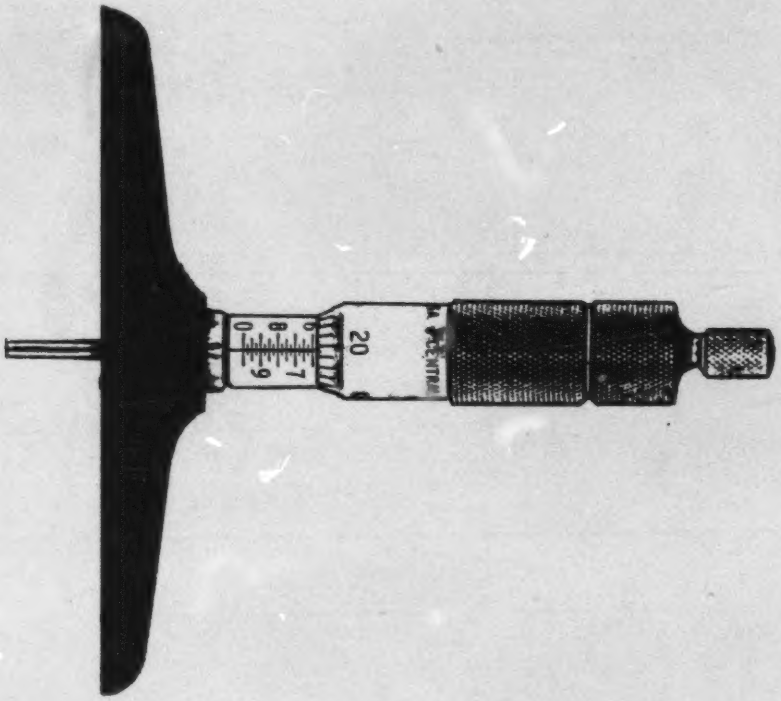
5. ________


0 1 2 3 4
20
U.S.A.
CENT
4THS
1 .250
3 .750
8THS
16THS
1 .0625
3 .1875
5 .3125
7 .4375
9 .5625
11 .6875
13 .8125
15 .9375
32NDS
9 .2812
11 .3437
13 .4062
15 .4687
17 .5312
19 .5937
21 .6562
23 .7187
25 .7812
27 .8437
29 .9062
31 .9687
THE CENTRAL TOOL CO.
CRANSTON, R.I.
U.S.A.

6. ________


0 8 6 7
5
OL CO. CRAN

7. ______



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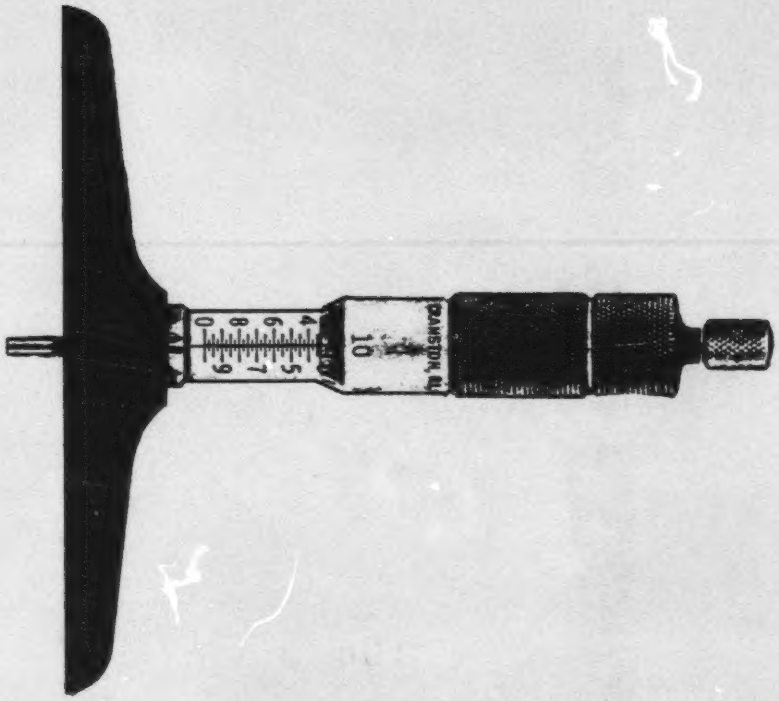
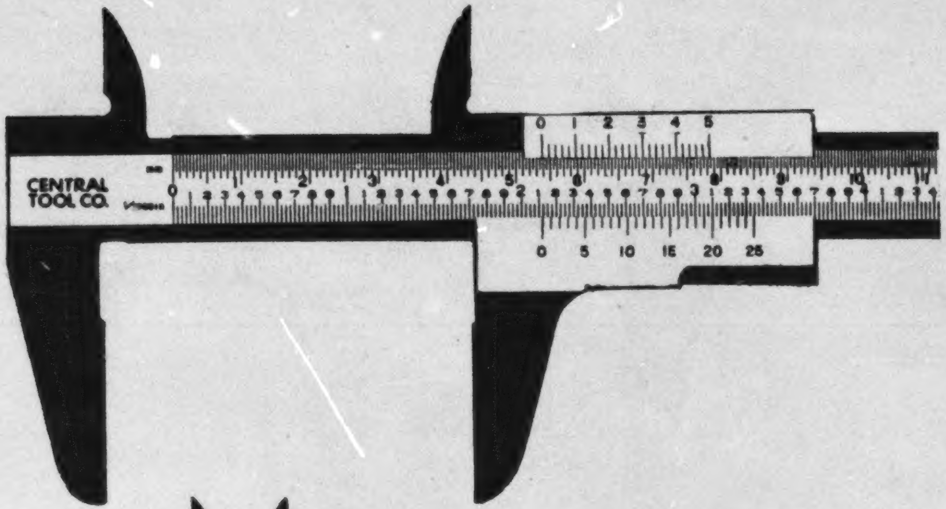

0
8
6
4
9
7
5
10
EVANSTON, ILL

9. ______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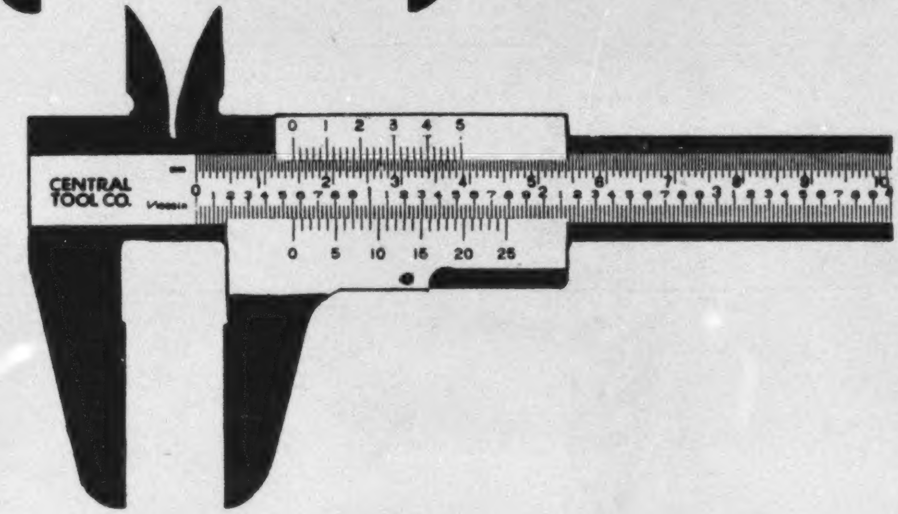
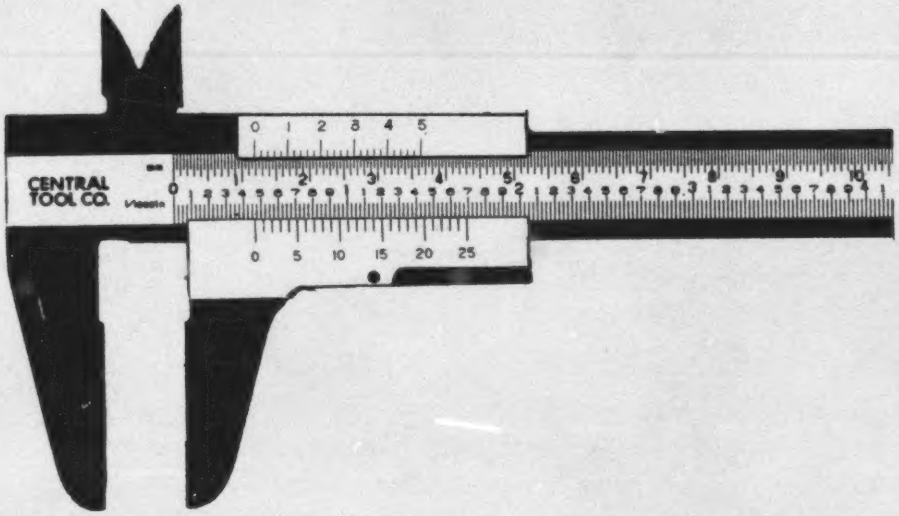
CENTRAL TOOL CO.
0 5 10 15 20 25

10. ______

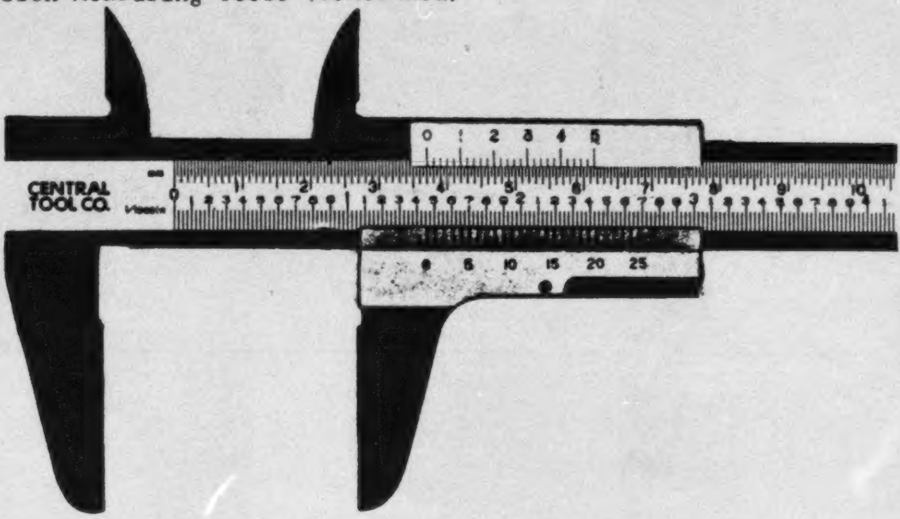

0 1 2 3 4 5
CENTRAL TOOL CO.
0 5 10 15 20 25

11. ______

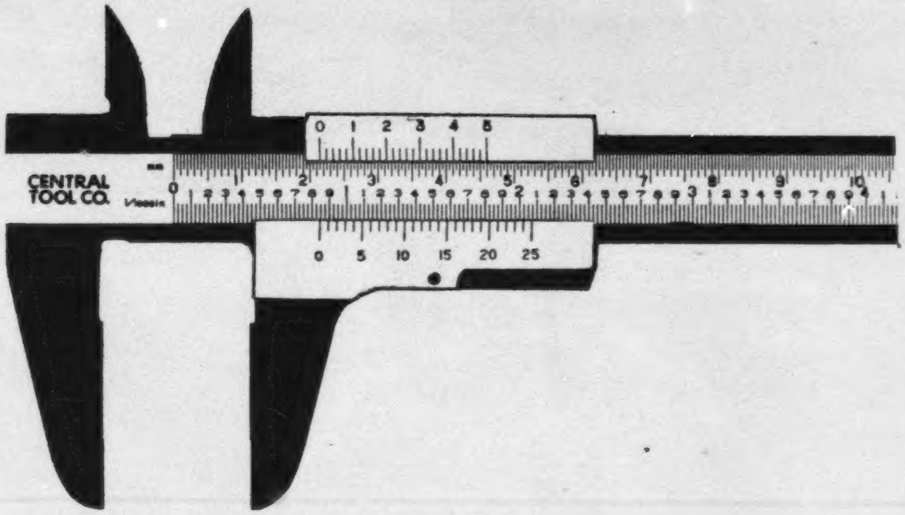

0 1 2 3 4 5
CENTRAL TOOL CO.
0 5 10 15 20 25

Reading Precision Measuring Tools *(continued)*

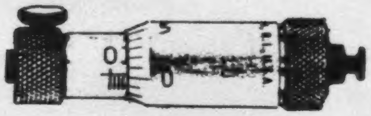
12. ______


CENTRAL TOOL CO.
0 1 2 3 4 5
0 5 10 15 20 25

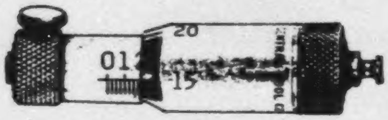
13. ______


CENTRAL TOOL CO.
0 1 2 3 4 5
0 5 10 15 20 25

14. ______



15. ______



APPENDIX 4

THE METRIC SYSTEM OF MEASUREMENT

The Metric System simply and logically coordinates the measurements of length, area, volume, and mass into one decimalized system. A base is used for each of the measurements and changes are accomplished by either multiplying or dividing the base by 10. For units smaller than the base, the prefixes used are deci for tenths, centi for hundredths, and milli for thousandths. For units larger than the base, the prefixes used are deka for tens, hecto for hundreds, and kilo for thousands.

The common metric units of length are the millimeter (mm) for small dimensions, the centimeter (cm) for daily practical use, the meter (m) (the basic unit) for dimensions of larger objects and short distances, and the kilometer (km) for longer distances.

Small areas are commonly measured in square centimeters (cm^2).

The common metric unit of volume is the liter, which is a cubic decimeter. Sometimes piston displacement is given in cubic centimeters.

The common metric unit of mass is the gram.

QUANTITY	UNIT	SYMBOL	RELATIONSHIP OF UNITS
Length	millimeter	mm	1 mm = 0.001 m
	centimeter	cm	1 cm = 0.01 m, 10 mm
	decimeter	dm	1 dm = 0.1 m, 10 cm, 100 mm
	meter	m	1 m = 10 dm, 100 cm, 1000 mm
	kilometer	km	1 km = 1000 m
Volume	cubic centimeter	cm^3	1 cm^3 = 0.001 ℓ
	millileter	mℓ	1 mℓ = 0.001 ℓ
	cubic decimeter	dm^3	1 dm^3 = 1ℓ, 1000 mℓ
	liter	ℓ	1 ℓ = 1000 mℓ
	cubic meter	m^3	1 m^3 = 1000 ℓ
Mass	milligram	mg	1 mg = 0.001 g
	gram	g	1 g = 1000 mg
	kilogram	kg	1 kg = 1000 g
	ton (metric)	t	1 t = 1000 kg

APPENDIX 5

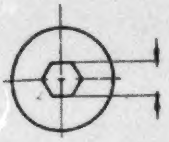
METRIC MEASUREMENT

Directions: Place the length of each line in millimeters in the place provided to the left of the line.

1. (47)
2. (38)
3. (42)
4. (27)
5. (35)
6. (32)
7. (17)
8. (7)
9. (23)
10. (12)

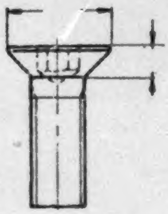
Directions: Place the indicated dimension in millimeters in the place provided to the left of the figure.

1. (5)

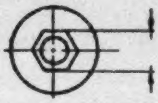


2. (15)

3. (5)

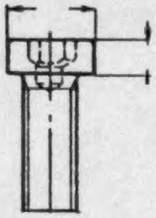


4. (6)

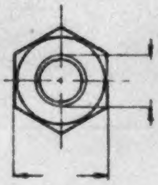


5. (13)

6. (5)

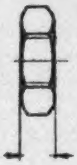


7. (7)

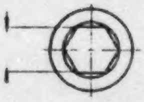


8. (14)

9. (5)

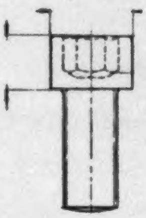


10. (7)

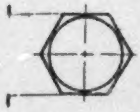


11. (12)

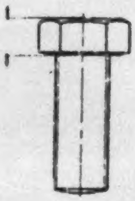
12. (13)



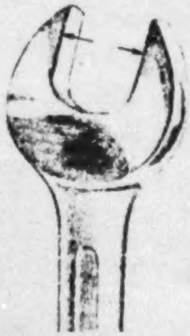
13. (12)



14. (5)



15. (12)



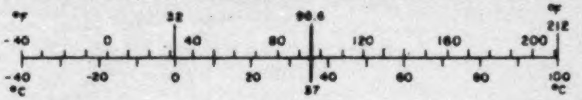
APPROXIMATE CONVERSION CHARTS

FROM METRIC TO CONVENTIONAL

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
MASS (weight)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

FROM CONVENTIONAL TO METRIC

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



EQUIVALENCY CHART

MILLIMETER EQUIVALENTS OF FRACTIONS AND DECIMALS

MM	Frac.	Inches	MM	Frac.	Inches	MM	Frac.	Inches	MM	Frac.	Inches
01		.0004	8.3344	21/64	.3281	21.4312	27/32	.8437	57		2.244
02		.0008	8.7312	11/32	.3437	21.8281	55/64	.8594	58		2.283
.03		.0012	9.000		.3543	22.000		.8661	59		2.323
.04		.0016	9.1281	23/64	.3594	22.2250	7/8	.875	60		2.362
05		.0020	9.525	3/8	.375	22.6219	57/64	.8906	61		2.402
06		.0024	9.9219	25/64	.3906	23.000		.9055	62		2.441
.07		.0028	10.000		.3937	23.0187	29/32	.9062	63		2.480
.08		.0032	10.3187	13/32	.4062	23.4156	59/64	.9219	64		2.520
09		.0035	10.7156	27/64	.4219	23.8125	15/16	.9375	65		2.559
.10		.004	11.000		.4331	24.000		.9449	66		2.598
.20		.008	11.1125	7/16	.4375	24.2094	61/64	.9531	67		2.638
.30		.012	11.5094	29/64	.4531	24.6062	31/32	.9687	68		2.677
.3969	1/64	.0156	11.9062	15/32	.4687	25.000		.9843	69		2.717
.40		.0158	12.000		.4724	25.0031	63/64	.9844	70		2.756
.50		.0197	12.3031	31/64	.4844	25.400		1.000	71		2.795
.60		.0236	12.700	1/2	.500	26		1.024	72		2.835
.70		.0276	13.000		.5118	27		1.063	73		2.874
.7937	1/32	.0312	13.0968	33/64	.5156	28		1.102	74		2.913
.80		.0315	13.4937	17/32	.5312	29		1.142	75		2.953
.90		.0354	13.8906	35/64	.5469	30		1.181	76		2.992
1.000		.0394	14.000		.5512	31		1.220	77		3.031
1.1906	3/64	.0469	14.2875	9/16	.5625	32		1.260	78		3.071
1.5875	1/16	.0625	14.6844	37/64	.5781	33		1.299	79		3.110
1.9844	5/64	.0781	15.000		.5906	34		1.339	80		3.150
2.000		.0787	15.0812	19/32	.5937	35		1.378	81		3.189
2.3812	3/32	.0937	15.4781	39/64	.6094	36		1.417	82		3.228
2.7781	7/64	.1094	15.875	5/8	.625	37		1.457	83		3.268
3.000		.1181	16.000		.6299	38		1.496	84		3.307
3.175	1/8	.125	16.2719	41/64	.6406	39		1.535	85		3.346
3.5719	9/64	.1406	16.6687	21/32	.6562	40		1.575	86		3.386
3.9687	5/32	.1562	17.000		.6693	41		1.614	87		3.425
4.000		.1575	17.0656	43/64	.6719	42		1.654	88		3.465
4.3656	11/64	.1719	17.4625	11/16	.6875	43		1.693	89		3.504
4.7625	3/16	.1875	17.8594	45/64	.7031	44		1.732	90		3.543
5.000		.1969	18.000		.7087	45		1.772	91		3.583
5.1594	13/64	.2031	18.2562	23/32	.7187	46		1.811	92		3.622
5.5562	7/32	.2187	18.6532	47/64	.7344	47		1.850	93		3.661
5.9531	15/64	.2344	19.000		.748	48		1.890	94		3.701
6.000		.2362	19.050	3/4	.750	49		1.929	95		3.740
6.3500	1/4	.250	19.4469	49/64	.7656	50		1.969	96		3.780
6.7469	17/64	.2656	19.8433	25/32	.7812	51		2.008	97		3.819
7.000		.2756	20.000		.7874	52		2.047	98		3.858
7.1437	9/32	.2812	20.2402	51/64	.7969	53		2.087	99		3.898
7.5406	19/64	.2969	20.6375	13/16	.8125	54		2.126	100		3.937
7.9375	5/16	.3125	21.000		.8268	55		2.165			
8.000		.315	21.0344	53/64	.8281	56		2.205			

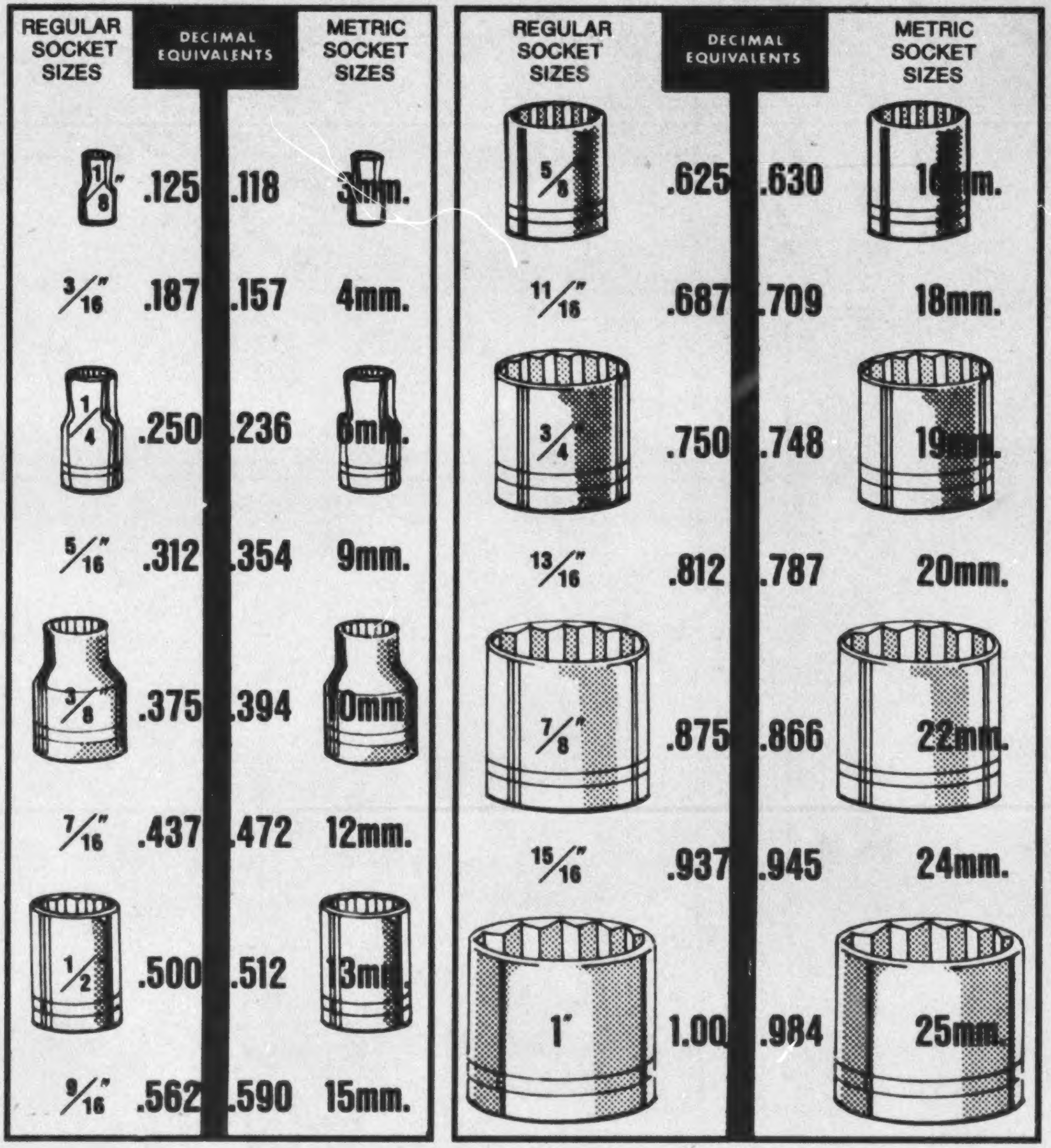
APPENDIX 8

SOCKET COMPARISON CHART *

Use this chart to familiarize yourself with the approximate "working end" size of metrics as compared to standard.

A word of caution: In some cases, a standard wrench or socket will fit on a metric bolt (they're that close). But, they don't *really* fit, and you take the chance of chewing up the bolt or skinning your knuckles but good.

It can't hurt, however, to "eyeball" the two systems side by side and get a feeling for what is what. And that's what this chart is all about.



REGULAR SOCKET SIZES	DECIMAL EQUIVALENTS		METRIC SOCKET SIZES
1/8"	.125	.118	3mm.
3/16"	.187	.157	4mm.
1/4	.250	.236	6mm.
5/16"	.312	.354	9mm.
3/8"	.375	.394	10mm
7/16"	.437	.472	12mm.
1/2	.500	.512	13mm.
9/16"	.562	.590	15mm.

REGULAR SOCKET SIZES	DECIMAL EQUIVALENTS		METRIC SOCKET SIZES
5/8	.625	.630	16mm.
11/16"	.687	.709	18mm.
3/4	.750	.748	19mm.
13/16"	.812	.787	20mm.
7/8"	.875	.866	22mm.
15/16"	.937	.945	24mm.
1"	1.00	.984	25mm.

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*Chart used by permission of *Magic Circle* magazine.

CYLINDER HEAD INSPECTION WORKSHEET

Student's Name ______________________________ Class ____________________

Engine Make ____________________ Model No. ____________________ Serial No. ____________________

Cylinder Head Bolt Torque ____________________ Valve Clearance: In. ____________ Ex. ____________

Valve Face Angle: In. ____________ Ex. ____________ Valve Seat Angle: In. ____________ Ex. ____________

Valve Guide Length: In. ____________ Ex. ____________ Valve Insert Dimensions: In. ____________ Ex. ____________

Inspection: Cracks ____________________ Pressure Check ____________________ Warpage ____________________

PART	SPECS.		CYL. 1		CYL. 2		CYL. 3		CYL. 4		CYL. 5		CYL. 6		CYL. 7		CYL. 8	
	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.	In.	Ex.
Valve Guide I.D.																
Valve Stem Dia.																
Stem to Guide Clear.																
Valve Guide Depth																
Valve Margin																
Valve Seat Width																
Valve Bridge Stem Dia.																
Valve Bridge Guide I.D.																
Valve Stem Protrusion																
Valve Head Protrusion																
Valve Spring Free Length																
Valve Spring Tens. Length																
Valve Spring Inst. Length																
Roto Cap Clear., if used																
Rocker Arm Bushing I.D.																
Rocker Arm Dia.																
Rocker Arm-Shaft Clear.																
Rocker Arm-Valve Contact																
Pushrod Condition																
Inj. Tube Condition																

ENGINE BLOCK INSPECTION WORKSHEET

Student's Name ______________________________ Class ______________________________

Engine Make __________________ Model No. __________________ Serial No. __________________

Main Bolt Torque __________________________ Rod Bolt Torque __________________________

ITEMS	SPECS.	FINDINGS
Block General condition		
Contact surfaces		
Core plugs		
Crankshaft Main Journals Diameter		
Taper		
Out of round		
Crankshaft Main Bearings Wear		
Out of round		
Alinement		
Clearance		
End play		
Bore		
Crankshaft Surface condition		
Oil passages		
Oil seal condition		
Alinement		
Counter weights		
Camshaft Condition		
Condition of lobes		
Alinement		

APPENDIX 10

Engine Block Inspection Worksheet *(continued)*

ITEMS	SPECS.	FINDINGS
Camshaft Bearings Wear		
Alinement		
Balanceshaft Bearings Wear		
Flywheel Contact surface		
Ring gear		
Alinement		
Pulleys Condition		
Vibration Dampers Condition		
Timing Gear or Chain Condition		
Oil Pumps Housing condition		
End plate condition		
Gear clearances		
Shaft bushing		
Piston and cylinder wear		
Pressure relief valve		
Oil galley Condition		

Use space below to record special information, such as flywheel runout, timing gear backlash, and timing gear markings.

Engine Block Inspection Worksheet *(continued)*

ITEMS	SPECS.	READINGS OR FINDINGS							
		Cyl. 1	Cyl. 2	Cyl. 3	Cyl. 4	Cyl. 5	Cyl. 6	Cyl. 7	Cyl. 8
Crankshaft Rod Journals Diameter									
Taper									
Out of round									
Crankshaft Rod Bearings Clearance									
End play									
Bore									
Pistons Condition of head									
Dia. of skirt top									
Dia. of skirt bottom									
Dia. of pin bushing									
Clearance to cylinder									
Ring side clearance 1									
2									
3									
4									
5									
Ring end gap 1									
2									
3									
4									
5									
Ring grooves and lands 1									
2									
3									
4									
5									

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Engine Block Inspection Worksheet *(continued)*

ITEMS	SPECS.	READINGS OR FINDINGS							
		Cyl. 1	Cyl. 2	Cyl. 3	Cyl. 4	Cyl. 5	Cyl. 6	Cyl. 7	Cyl. 8
Piston Pins									
Condition									
Diameter									
Clearance									
Connecting Rods									
Condition									
Pin bore wear									
Taper (big end)									
Cylinder Bore									
Wear									
Out of round									
Taper									
Cylinder Sleeve									
O.D.									
Protrusion									
Surface condition									
Tappets and Cam Followers									
Condition									
Condition of contact surfaces									
Lifter body conditions									
Plunger conditions									
Leak down rate									
Pushrods									
Condition of contact surfaces									
Length									
Alinement									